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Some Effects of Calcium on Growth, Yield and Mineral Content of Pepper (Capsicum Annuum L.).

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SOME EFFECTS OF CALCIUM ON GROWTH, YIELD AND MINERAL CONTENT OF PEPPER (*CAPSICUM ANNUUM* L.)

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by
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ABSTRACT

Two different greenhouse experiments were conducted to determine the effects of sources and levels of Ca on the growth, yield and mineral contents of bell pepper (_Capsicum annuum_ L.) cv. 'Keystone Resistant Giant #4' grown on Cahaba silt loam.

The $CaCO_3$ produced plants that had significantly better growth, greater yield and higher nutrient uptake than did the control plants during the spring, summer and fall tests. Quality of growth, earliness of flowering and fruit development were better during the fall plantings for all treatments.

The $Ca(NO_3)_2$ favored more vegetative growth on short internodes during the summer planting. Although a general yield depression was observed, spring planting had larger fruit production.

Depression of soil pH with $CaSO_4$ was greater during the fall planting. This resulted in decreased macronutrient availability. Interveinal chlorosis on the upper leaves of pepper plants occurred due to levels of Mn in excess.

The excessive heat of summer caused poor fruit-setting, limited pollination, nutrient uptake, more blossom drop and production of smaller fruits, resulting in overall lower yield than either fall or spring plantings.

Total mineral content was greater in the leaves, then stems and finally fruits. Uptake was greatest in fall, then spring and lastly summer. The P, K, Ca and Mg uptake generally increased significantly with increased Ca levels up to 1,500 ppm Ca as $CaCO_3$. The Mn, Zn and Fe content was greater at low levels of Ca and soil pH. A soil pH range of 7.2 to 7.4 obtained by applying 1,500 ppm $CaCO_3$ during the fall was considered optimum for bell pepper growth and yield on Cahaba silt loam soil under greenhouse conditions.

Percent dry matter was greatest in the stems, then leaves and lastly fruits, and generally increased in each case with increase in Ca levels. Summer plants had the higher dry matter percentages.

Abundant Ca resulted in the production of smaller plants, but stimulated early and higher yield in the fall test.

Fruit yield was positively correlated with plant height, plant width, leaf area, length of fruit, diameter of fruit and number of lobes.

INTRODUCTION

Garden pepper, a frost-sensitive, warm-season solanaceous crop of the genus *Capsicum* is thought to be native to tropical America. It is noted for its green (immature) and yellow or red (mature) edible fruits, which vary in size and shape (69). Virtually all cultivated pepper belong to the species, *C. annuum*. Tabasco is the only cultivar of *C. frutescens* grown commercially in the United States.

Pepper (sweet) cultivars recommended for Louisiana production include 'Keystone Resistant giant #3 or 4', 'Resistant Florida Giant', 'Emerald Giant', 'Bell boy' (hybrid), 'Yolo Wonder', 'Miss Bell' and 'Yolo L.' (9). Among the leading vegetables grown in Louisiana, sweet pepper is ranked 5th, being surpassed by sweet potatoes, watermelons, southernpeas and Irish potatoes in descending order (71). A total of about 1,095 acres have been devoted to its production in such areas as Tangipahoa, St. James, Jefferson, St. Landry, St. Charles, Rapides, Ascension, Plaquemines, Lafourche, Caddo and Webster parishes.

The U.S.D.A. records showed that in 1973, Louisiana produced 1.6% of the total green peppers in the United States with 1,400 acres harvested (78).

By 1981, there were only about 110 acres of Tabasco peppers being grown in Iberia Parish, in Louisiana because of the absence of satisfactory harvesting method (10). Total production in the parish represented less than 10% of the total quantity processed. More than 90% of the Tabasco peppers processed and sold in Louisiana are imported from Central and South America.

Cayenne peppers are one of the most important horticultural crops grown in Louisiana for the processing industry (46).

Pimientos are often used to enhance the qualities of other foods because of their red color and characteristic flavor (18). In pharmaceuticals, the pungent characteristic of Capsicum makes them important (48). Edible portions of sweet peppers are good sources of protein, carbobydrates, fats, essential minerals and such vitamins as vitamin A, thiamine, riboflavin, niacin and ascorbic acid (6).

In view of the importance of this crop, it is necessary that any factor which affects yield and cost of production should be given adequate consideration. Any economy in the purchase of fertilizers or any change in our present methods of growing the crop which would result in higher cash returns would be of material benefit to pepper growers.

Moreover, information on nutrient absorption is important because a knowledge of the kind and amount of nutrients absorbed at intervals throughout the growing season gives a better understanding of the fertilizer requirements for a more successful cultural program.

The objectives of these studies were:

1. To investigate the effect of calcium source, soil pH, and growing season on bell pepper growth, yield and foliar mineral content.
2. To determine the optimum rate of calcium carbonate and soil pH for growth and development of bell pepper grown on a Cahaba silt loam soil, pH 4.9 - 5.0.

LITERATURE REVIEW

Poincelot (69) considered Florida, California, North Carolina, Texas and New Jersey as the Leading commercial producers of peppers in the United States.

The U.S.D.A. records showed that in 1973, approximately 4,718,000 cwt. of green peppers were produced and were valued at about $65,002,000 (79). The records added that in the same year Louisiana produced 1.6% of the total green peppers in the United States with 1,400 acres harvested.

Montelaro et al (54) reported that Louisiana peppers require fertilizer at the rate of 800 to 1,500 pounds of 6-12-6, 5-10-10 or equivalent per acre, applied two weeks before transplanting plus 16 pounds of readily available nitrogen as a side-dressing.

Based on the results obtained from his 3- to 5- years trials at Plaquemines Parish Experiment Station in Louisiana, Adams (1) found that 'Emerald Giant', 'Big Pak', 'Grande Riobb', and 'Green Boy' produced higher yields than other pepper cultivars tested.

Etzel and Hernandez (23) in their effort to discover bell pepper cultivars best suited for northeast Louisiana reported that 'Miss Bell', 'Bell Boy' (Hybrid), 'Yolo L.', 'Mississippi 68', 'Emerald Giant', and 'Keystone Resistant' out yielded all others tested.

Miller (53) stated that pepper plants treated with low calcium solutions were stunted and had very dark green leaves. Although some fruits had blossom-end rot, they were well shaped, smaller and darker green than normal fruits.

Chiba (13) observed that Capsicum plants grown on a soil pH of 6.5 had greatest plant height (130 cm), most uniform growth, highest root weight, production, and more nutrient uptake. He noted that a pH of 7.2 was considerably better for crop growth than 7.9. Such pHs were obtained by adding different amounts of calcium carbonate.

Zaubin (82) showed that liming resulted in increased growth and development of pepper roots. He considered the pH range of 5.6 to 5.8 as optimum for pepper growth in Bangka Island of Indonesia.

Carolus (11) reported that calcium played an important part in potato development besides creating a favorable soil environment for growth. He also pointed out that calcium has an indirect effect on the growth of the plant by altering the availability of certain nutrients and preventing the toxic effects of others. He also noted that potatoes grow well in acid soils at pH values between 4.8 and 5.5.

Nightingale et al. (56) indicated that calcium deficient tomato plants in water cultures were weak, flabby, and lacking in firmness or turgidity. Their terminal buds died, and their stems near the terminal became spotted with dead areas. Roots were short, much branched, stubby, bulbous and dark brown in color.

Studying the response of tomato plants to calcium, Kalra (40) found that tomato plants grown in 0 ppm calcium developed typical deficiency symptoms in both sand and water cultures, but when transferred to solutions with 160 ppm calcium, growth and leaf production, which had been limited, increased. The ratio of floral to vegetative apices and the development of flower buds were greater at 40 than at 160 ppm. With few exceptions, per cent dry weight was increased by calcium deficiency. Total cross-sectional and per cent steele tissue in internodes and hypocotyls were positively correlated with calcium levels.

Sachan and Sharma (72) stated that the amount of calcium absorbed by tomato seedlings in nutrient solution high in calcium (5 meq/l) was significantly correlated with root length, surface area, and fresh and dry weights.

From soiless culture experiments with the tomato cv. 'Extase CF', Matev and Stanchev (50) discovered that plant development was depressed by antagonism between Ca^{++}, Mg^{++}, or Na^{+} and K^{+}.

Fernandes and Haag (24) found symptoms of N, P, K, Ca, Mg and S deficiencies on capsicum cv. Avelar grown in pots. The greatest reduction in plant growth was with solutions deficient in calcium and nitrogen.

Osawa and Ikeda (58) reported that excess Mn induced interveinal chlorosis on upper leaves of bean, eggplant, pepper and spinach but increasing the supply of K and Ca reduced the severity of Mn- induced chlorosis. This beneficial effect was generally more marked with Ca than with K. Increasing the supply of K and Ca was effective in alleviating the growth reduction of the vegetable crops due to excess Mn. This effect was also more marked with Ca than with K.

Two years later Osawa and Ikeda (59) stated that zinc excess induced interveinal chlorosis on upper leaves in eggplant, pepper, cabbage and spinach. They noted that increasing the supply of K and Ca reduced the severity of Zn-induced chlorosis. There was not such a marked difference between the beneficial effect of K and that of Ca. Increasing the supply of K and Ca was effective in alleviating the growth reduction of vegetable crops due to zinc.

In 1975, Dyson and Digby (20) observed that 'Majestic' potatoes sprouted in the dark at $20^{o}C$ developed necrotic lesions in the elongating region of the sprout, about 3 to 5 mm below the apex due to calcium deficiency. They noted also that frequent application of 0.01 micron $CaSO_4$ solution to the tips of the sprouts fully controlled the deficiency of calcium. They finally reported that calcium was necessary to maintain apical dominance of the sprout and prevented some of the changes which have been attributed to physiological aging.

Later in the same year, Dyson and Digby (21) found that by treating the sprouts of ten potato cultivars, grown from

5-g tuber pieces with either distilled water or 0.01 micron $CaSO_4$ solution daily , calcium application was necessary to maintain growth of the main sprout in all cultivars. In the absence of added calcium, apical dominance was lost and lateral branches developed. They also noted 'little potato' disorder in cv. Pentland Dell.

Hall (32) stated that tomato plants grown in nutrient solutions containing 0.05, 0.2, 1.0, 15.0 and 30.0 meq Ca/l showed Ca deficiency symptoms for those at lowest levels of Ca which also produced least dry matter.

Wallace and Grazzar (81) reported that tomato cv. Tropic, grew satisfactorily in solution cultures containing an excess of $CaCO_3$ as the only source of Ca, and 0.05 micron Fe EDDHA. Although the pH of the solution exceeded 7, there was no sign of Fe deficiency.

Pandev et al. (63) reported that capsicum cv. Zlaten Medal grown in soiless culture with complete nutrient solution and with solutions deficient in N, S, P, K Ca, or Mg showed adverse effects of deficiency of individual nutrients on photosynthetic rate in the order N › P › Ca › K › Mg › S. Similar rankings of adverse effects of nutrient deficiencies were given for chlorophyll content, leaf area, and biological productivity.

Studying the fertilizer and liming practices best for South Carolina, Cooper (16) stated that 4,000 lbs. of limestone per acre broadcast applied annually is the minimum required for a desirable condition for pepper production on the sandy loam soil in South Carolina if the soil pH range lies between 4.5 - 5.0. Above pH 6.01, he recommended 1,000 lbs. limestone broadcast or 200-300 lbs in row with fertilizer.

Parker et al. (64) reported that on a fertile soil with a pH of 5.4, capsicum yields were not increased by fertilizer nutrients or lime. They, however, indicated that on an acid soil of low fertility capsicum yields were increased by N, P, and K, especially when lime was also applied.

In 1960, Harrington (35) pointed out that pepper plants grown under severe nutrient deficiencies showed various deficiency symptoms, including necrosis of the growing tips, with calcium deficiency, and necrotic spots along the leaf margins in the case of potassium deficiency. Seed yields were always depressed by low N,P,K or Ca treatments.

Ozaki and Hortenstine (60) stated that application of lime increased yields of 'Florida Giant' peppers only if the acid-soluble calcium level was below 300 lbs. per acre. On such soils an application of 2,000 lb agricultural limestone per acre resulted in the highest yield of marketable (U.S. fancy + U.S. No.1) peppers.

Singh and Nettles (74) found that weekly removal during a 23-day period of flowers before fertilization, or of young developing fruits, resulted in taller plants and higher yields than when plants were not deblossomed or defruited. By increasing calcium levels from 0 to 1,000 lbs per acre plant height was significantly increased but yield was reduced. However, an increase in calcium application reduced the incidence of blossom-end rot.

A study conducted by Gerber et al. (31) showed that amending sandy soil with liquid sewage sludge increased soil content of P, K, Ca, Mg and Cd. The yield of capsicums, eggplants and tomatoes rose on sludge-amended soil compared with soil receiving inorganic NPK fertilizers.

Forsee et al. (26) found that the 14 different vegetables tested on the sandy soils of the Immokalee and Sunniland series showed yield increases up to a pH of approximately 5.50 to 5.70 except sweet corn which showed an improvement in quality and earliness of maturity. Beyond the above range, pepper, eggplant, tomato and snap beans still responded to lime application.

Odland and Albritten (57), looking at soil reaction and calcium supply as factors influencing yields of potatoes and the occurrence of scab, reported that on a very fine sandy loam in Rhode Island, little differences in yield occurred in the pH range of 4.5 to 6.5, with or without 100 or 200 lbs per acre of limestone or gypsum.

From his study on potatoes, Fiskell (25) showed that both gypsum and calcite limestone, applied prior to forming the bed and fertilization were effective in promoting better yields. He also noted that where large amounts of dolomite were used, lower yields occurred because less large-sized potatoes developed. Soil calcium supply correlated very positively with the yield of U.S. Grade A potatoes.

Lundberg et al. (47), determined the yield and elemental composition of potatoes cv. 'Kennebec' grown on soil amended with fluidized-bed combustion waste, using hydrated lime, MgO and $CaSO_4$ to supply equivalent of liming power, Mg and S. They reported that no significant differences were found in yield and elemental composition of potatoes grown with fluidized-bed combustion waste or other amendments.

Based on an experiment on the liming for tomatoes on acid sandy soils, Hayslip and Ozaki (36) indicated that no advantage was derived by using mixtures in place of single liming sources. Dolomite appeared to be less effective in reducing blossom-end rot. They also reported that all liming experiments produced better yields, much less blossom-end rot and higher calcium and magnesium contents of fruits than unlimed check plots.

Beckenback(4) observed reduced yields of tomatoes with high lime treatments on a Bradenton fine sandy loam. Two years later he noted no yield response in the same crop with pH increases from 4.8 to 6.8.

In sand culture studies, Campbell and Swingle (8) found that low levels of Ca, Mg or K reduced the fresh weight and ash content of sweet pepper fruits. Plants receiving low K levels showed deficiency symptoms on the leaves before the flowering stage was reached.

Dempsey and Boswell (17) reported that the plant weight of Capsicum cv. 'Truhart Perfection' was more closely related to soil K and Mn levels than soil Mg in a greenhouse study. Plant Mg levels were increased significantly by magnesium sulphate or dolomitic limestone additions.

Perez (68) indicated from his study on the mineral and protein content of large red peppers that the mineral content of red peppers from Chile ranged from 0.10 to 0.14% Ca, 0.11 to 0.23% Mg, 0.21 to 0.51% P, 0.01 to 1.58% K, 0.34 to 0.41% Na, 0.032 to 0.038% S, 0.007 to 0.0085% Fe, 0.001 to 0.002% Mn and 0.004 to 0.008% Cu.

Ozaki and Ozaki (61) showed that side-dress applications of hydrated lime at the rates of 300 and 600 lbs per acre, or Ca sprays containing 4 lbs. of $CaCl_2$ per 100 gallons of water resulted in no significant differences in Ca, Mg, P and K in pepper plants.

Fouad and Biswas (27) found that with the exception of Fe, which fluctuated in the fruits at the various stages of development of pimiento peppers, Ca, K and P accumulated in the fruit as it advanced in ripening. They also discovered that more mineral elements are found in ripe fruits than at earlier stages of growth and development.

Hoffman et al. (37) reported from their study on Capsicum grown in 5 liter containers supplied with 0.6 gm N, 0.349 gm P_2O_5, 0.996 gm K_2O, 0.181 gm Mg and 0.2 gm of a minor element polychelate (LS-7) per container that the fresh weight and the N, P, K, Ca, Mg and Na contents in leaves, shoots, roots, fruits and seeds were greater for plants receiving the double rates of N, K, Mg and LS-7 with the P rate remaining constant.

Investigating the alterations in growth and metabolism of potato plants by calcium deficiency, Singh and Sharma (75) reported that meristematic regions at stem and roots were severely affected and ultimately ceased to grow. Plants remained stunted with few and smaller tubers. The P, K, Ca and Na contents were lower and Mg content higher in the deficient plant than that of the healthy ones.

Tomato cvs. 'Ventura', 'Khebros' and VF-198 grown in gravel culture with varying ratios of N, P and S anions and K, Ca and Mg cations in the nutrient solution, had high N and Ca levels in the leaves which promoted chlorophyll a and b and carotenoid accumulation. High tissue P and S reduced chlorophyll synthesis (28).

Hamson (34) noted that calcium content was positively correlation with firmness in fresh tomato fruits. He added that calcium in fruits may be related to both crack resistance and firmness, since the two qualities are probably dependent on cell wall strength.

Agui et al. (2) reported that K, Ca, and Mg uptake by hydroponically-grown plants of tomato depended on the amount of these elements in the nutrient solution, but the higher the nutrient concentration in the solution, the lower was its relative concentration in the shoot.

In a study to clarify the effects of flowering and fruiting on calcium absorption in both the vegetative and reproduction phase of some vegetable crops, Chen and Uemoto (12) stated that the reproductive phases had a higher percentage Ca content in the leaves of vegetable crops. In tomato and eggplant, the content of Ca in the leaves increased in proportion to the number of fruit set, and decreased after the fruit was harvested. They therefore discovered that a cyclic change in Ca content occurred in parallel with growth cycle of the plants.

Ozaki and Ozaki (62) reported that application of 4,000 lbs per acre of hydrated lime significantly reduced pepper fruit blossom-end rot number.

In contrast, increasing the rates of N and K_2O in a side-dressing, resulted in a significant linear increase in the number of blossom-end spot fruit.

Geraldson (29) indicated that there exists a relationship between calcium availability and blossom-end rot of peppers. He added that the blossom-end rot of peppers caused by a deficiency of Ca, or by excess soluble salts in the substrate, could be controlled by 0.04 micron calcium chloride spray applied approximately every five days.

It has been reported (3) that 22% of the pepper fruits picked from plants grown in a medium low in calcium at Clemson, South Carolina showed lessions of blossom-end rot.

It was concluded that calcium deficiency in soil may cause blossom-end rot in peppers.

Miller (53) found visual symptoms of deficiencies or excesses of N, P, K, Ca and Mg as they appeared in the foliage or fruit of sweet pepper plants grown in sand culture at various levels of these elements. The incidence of blossom-end rot was found to be directly related to calcium deficiency, which resulted either when the calcium concentration in the nutrient solution was low, or when cations such as NH_4 or K were very high.

Hamilton and Ogle (33) noted that low calcium resulted in 25.5% of pimiento peppers developing blossom-end rot. No such disorder occurred at the high level of calcium. They also stated that magnesium indirectly increased blossom-end rot by depressing uptake of calcium, as indicated by both fruit and leaf tests. K influenced leaf calcium, but failed to influence blossom-end rot or calcium content of the fruit

Studying the calcium-related disorders of fruits and vegetables, Shear (73) reported that blossom-end rot of peppers is among the disorders recognized as being associated with a localized inadequacy of calcium. He indicated that this disorder caused by an inadequate level of calcium in affected tissue can be corrected by considering the entire physiology of uptake and translocation to the potentially affected tissues as well as making adequate adjustments to assure adequate calcium accumulation in these tissues.

Geraldson (30) pointed out that blackheart of celery and blossom-end rot of tomato and Capsicum were caused or enhanced by deficiency of soluble Ca and excess total salts, even with satisfactory Ca ratios.

Maynard (51), studying Ca deficiency disorders of vegetable crops, stated that a number of vegetable crop disorders caused primarily by Ca deficiencies were always found at or near the plants growing point or in fleshy storage organs such as fruit or roots. He added that blossom-end rot of tomatoes and peppers occurred because of an initially low Ca concentration in that portion of the fruit followed by restricted Ca movement to the fruit during stress periods.

From the study on blossom-end rot in tomato, Pereira et al. (67) indicated that with tomato cv. Rossol, liming with $CaCl_2$ (0.4%) or $CaSO_4$ (0.6%) reduced the disorder by 25% only but increased tomato yield by 18%.

Maynard et al. (52), in an experiment showing the effects of three levels of Ca nutrition on three tomato varieties grown in sand culture, found that the incidence and severity of blossom-end rot were decreased significantly as Ca levels were increased. Calcium content of normal fruit was significantly greater than that of blossom-end-rot-affected fruit. Calcium content of all fruit increased as Ca in solution increased. In a study on the control of both Blossom-end rot of tomatoes and Blackheart of celery, a U.S.D.A. Research staff (78) reported that low soil pH is a factor associated with a low calcium ratio. He added that due to lack of nitrification at a low soil pH, the accumulation of ammonium nitrate was favored. A combination of low soil Ca and excess soil NH_4^+ would be favorable for development of blossom-end rot or blackheart in tomatoes and celery, respectively.

Dickinson and McCollum (19) found that adding $CaCl_2$ to the water infiltrated in detached tomato fruits prevented cracking in a crack-resistant cultivar (KC146) and reduced the severity of cracking in susceptible cultivar 'Garden State'. They also noted that $CaCl_2$ reduced cracking in fruits of 'Garden State' when applied as a spray to intact plants. They concluded that application of Ca spray may become a useful method to decrease losses due to cracking.

MATERIALS AND METHOD

A preliminary experiment on the effect of sources of calcium on the yield, some growth characteristics and mineral content of bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 was conducted in the greenhouse at Louisiana State University in the Spring of 1982.

The experiment was conducted on a Cahaba silt loam obtained from the Hammond Research Station in Hammond Louisiana.

Soil test results indicated a soil pH of 4.9, medium extractable phosphorus and potassium (66 and 124 ppm, respectively), low magnesium (39 ppm) and very low calcium (200 ppm) (66). Soil organic matter was 0.49%. A supplemental application of magnesium as magnesium sulphate brought magnesium to medium level (85 ppm).

Based on the soil test results, the four treatments which were replicated four times included a control (no additional calcium), and 400 ppm Ca as calcium carbonate ($CaCO_3$), 400 ppm Ca as calcium nitrate ($Ca(NO_3)_2$) and 400 ppm Ca as calcium sulphate ($CaSO_4$). No supplemental application of carbonate, nitrate or sulphate ions were made since comparisons were between the control and each calcium source.

Sixteen plastic pots of 14 Kg capacity were used for the experiment. Each pot contained a layer of rocks, 1.27

cm thick, followed by a second layer of river sand, 1.27 cm thick, to improve drainage and aeration. Each calcium treatment was incorporated with 12 Kg of soil in each pot. The pots were moistened to field capacity and allowed to equilibrate.

A completely randomized experiment was designed and the pots were randomly assigned to positions on the bench (77).

Seeds of 'Keystone Resistant Giant #4' were seeded in peat pots in the greenhouse on February 28, 1982. At 20 days, 2 transplants were set in each pot. Pots were thinned to the one most vigorous seedling. Water was uniformly supplied as needed until harvest which was 80 days from the transplanting date. The number of flowers which opened each day was counted and the mean per treatment recorded at harvest.

At harvest, plant height, plant width, number of branches, fresh weight of shoot, yield, fruit length, fruit maturity, and fruit size were recorded.

Plant height was measured by means of a centimeter scale from the soil level to the apex of the tallest branch. Plant width measurements were taken between two apices of opposite leaves that were farthest apart on each plant. The number of branches was counted and the mean reported for each treatment. Fresh weight of the shoot was recorded as the weight of each plant cut at the soil level minus the fruit. The mean weights of the fruits collected at harvest was recorded in grams for each treatment. The mean fruit length was reported for each treatment. Visual ratings were used to categorize the fruits from each treatment, as to size, and maturity level at harvest. The percent dry matter was obtained as the ratio of dry weight to the fresh weight of the plant part, multiplied by 100.

Shoots and fruits were analyzed for mineral content at the Louisiana State University Soil Testing Laboratory. The dried plant materials were ground in a Wiley mill to pass a 0.5 mm mesh stainless steel screen. The ground tissue sample (0.5 gm) was wet-washed with 15 ml of 3:1 nitric: perchloric acid. Each beaker was covered with elevated watch glass and left under the hood overnight. The straw colored mixtures were cooked away the following morning until the solutions became jelly-like. On cooling, 15 ml of distilled water was added to each beaker, stirred properly before filtering into 50 ml volumetric flasks. To each flask was added 2 ml of Lanthanum solution (to tie up the phosphate on analysing for calcium) and the volume made up to the mark. These stock solutions were used to determine K, Ca, Mg, Mn, Zn, and Fe using atomic absorption spectrophotometry. The P was determined by ammonium molybdate-ascorbic acid colorimetric procedure. Values were transformed to $\arcsin\sqrt{\text{percentages}}$.

The data obtained from each character studied were analyzed by least significant difference procedure.

Since the calcium carbonate treatment proved statistically a better source of calcium for bell pepper production (Table 1-4), two additional experiments were established to study the effect of levels of $CaCO_3$ on bell pepper production.

Using fresh soil samples from the same soil source and the same procedures, these experiments were conducted in the greenhouse in the summer and Fall 1982.

Based on the results of soil analysis, five levels of calcium which were replicated four times for each experiment included the control (0), 500, 1,000, 1,500 and 2,000 ppm Ca, respectively, were applied as finely ground $CaCO_3$. Each treatment was incorporated with 12 Kg of soil in each of the twenty 14 Kg pots used for the experiments. Soil pH for these experiments was 5.0 whereas the organic matter content was 0.5%. Improved drainage and aeration were affected by providing a layer of rocks 2.54 cm thick, followed by a second layer of river sand which was also 2.54 cm thick.

For more reliable information, the source experiment was repeated concurrently with each of the two experiments on the levels of calcium. Based on the results of the soil analysis obtained after each harvest, supplemental applications of the essential plant nutrients brought the soil nutrient level to that of the original soil used for the preliminary experiment before it was be used again.

The temperature range during the duration of the study was from 70^{o} to $90^{o}F$ resulting in an average temperature of $80^{o}F$. Soil moisture in each pot was used near field capacity until plants began to bloom. A completely randomized design was maintained in each case. Seeds for summer planting were seeded in peat pots in the greenhouse on June 14, 1982 whereas those for fall planting were seeded on September 21, 1982. At 30 days, 2 transplants were set in each pot in both cases. Harvesting was done 80 days from the transplanting date as in the preliminary experiment.

A weekly application of a mixture of two fungicides (Daconil 2787 and Captan) and two insecticides (Cythion and Diazinon AG500) protected the plants from fungal and insect infections throughout the growing period for each experiment. Weed control was partly done by hand and partly by superficial digging (less than 5 cm deep) with a hand trowel in some cases.

In addition to the characters studied during the preliminary experiment, leaf area, leaf abscission, bud drop, fruit abscission, fruit diameter and number of lobes data were also collected.

Percentages observed for mineral content, dry matter and fruit abscission were transformed to arc sin $\sqrt{\text{percentages}}$ for analysis. These and other characters studied in the source experiments were statistically analyzed by the least significant difference test whereas similar data recorded for the calcium level experiments were statistically analyzed according to Duncan's new multiple range test; because of the nature of comparisons made in each case (77).

EXPERIMENTAL RESULTS AND DISCUSSION

Preliminary Greenhouse Experiment (Spring 1982)

Bell pepper (*Capsicum annuum* L.)

An experiment was conducted to determine the effects of sources of Ca, soil pH and season on bell pepper growth, yield and mineral content. The effects of $CaCO_3$ on plant height, plant width, number of branches, number of flowers, fresh weight of shoot and yield are presented in table 1. Plant height, plant width, number of branches and shoot fresh weight were not significantly affected by Ca treatment. The number of flowers and yield were significantly affected by Ca treatment. The greatest number of flowers was 9.00 which was observed in the 400 ppm $CaCO_3$ treated plants. The smallest number of flowers was 7.00 in the control plants. An adequate Ca supply is essential for flower production in bell pepper, if other growth factors do not limit the plants. The maximum yield 41.5 g, was observed in the 400 ppm $CaCO_3$ treated plants. The lower yield was 7.00 g in the control plants. Poor yield noted for the control was attributed to insufficient Ca uptake by the plants. Mascarenhas and Machlis (49) discovered that like root growth, the growth of the pollen tube in '*Antirrhinum* was markedly stimulated by Ca. Since growth of the pollen tube to the ovule is a response to a gradient of Ca content from the stigma to the ovule, inadequate Ca uptake could have prevented fertilization thereby preventing better fruit

Table 1.

Effects of $CaCO_3$ on growth, flowering, shoot fresh weight and yield of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches/plant	Number of flowers/plant	Fresh weight shoot (gm)	yield (gm)
0	16.80	18.68	5.50	7.00	11.75	7.00
400	16.88	19.50	5.50	9.00	13.60	41.50
Average	16.84	19.09	5.50	8.00	12.68	24.25
C.V.,%	12.18	10.23	17.68	10.91	19.00	22.02
$LSD_{.05}$	NS	NS	NS	1.17	NS	8.68

production in the control plants. The higher production noted from the $CaCO_3$ treated plants was due to an improved soil pH range of 5.4 to 5.6. Since Ca availability is greater at such a pH range than the lower pH range of 4.8 to 5.1 from the control treatment, Ca may be considered essential for normal growth and development of pepper plants. Beeson (5), reported that the concentration of Ca in leaves of higher plants generally range from 0.2 to more than 5% of dry weight. Nicholas (55) discovered that Ca is also required by some algae or other micro-organisms in micronutrient quantities only.

The effects of $CaCO_3$ on fruit length, shoot and fruit percent dry matter, fruit maturity, and fruit size are shown in table 2. Percent dry matter in the shoot was not significantly affected by addition of $CaCO_3$. Fruit length and percent dry matter in the fruit were significantly affected by Ca treatment. The greatest fruit length was 5.58 cm which was observed in the 400 ppm $CaCO_3$ treated plants. The smallest fruit length was 2.55 in the control treatment. This value was significantly lower than the 5.58 cm observed in the 400 ppm $CaCO_3$ treated plants. These values were lower than 8.89 to 11.43 cm range reported by Montelaro et al. (54) as possible fruit lengths for most popular mild-fleshed cultivars grown for fresh market or for processing in Louisiana. The higher percent dry matter in the fruit was 7.33 which was observed in the 400 ppm $CaCO_3$ treated plants. The lower

Table 2.

Effects of $CaCO_3$ on fruit length, percent dry matter of shoot and fruit, fruit maturity, and fruit size of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Fruit length (cm)	Percent D.M. shoot	Percent D.M. fruit	Fruit maturity	Fruit size
0	2.55	15.13	3.75	I^{Y}	VS^{Z}
400	5.58	16.15	7.33	MT	M
Average	4.05	15.64	5.54	-	-
C.V.,%	13.34	11.32	11.38	-	-
$LSD_{.05}$	1.66	NS	1.84		

^{Y}I = Immature, MT = Mostly mature

^{Z}VS = Very Small, M = Medium

percent dry matter was 3.75 in the control plants. Higher Ca application may account for greater percent dry matter for the plants under $CaCO_3$ treatment. Both visual rating and fruit firmness indicated that fruits from 400 ppm $CaCO_3$ treated plants were mostly mature at harvest. Those from the 400 ppm $CaCO_3$ treated plants were over 4 cm, but less than 6 cm in length, hence were considered medium in size. Fruits from the control treatment were 3 cm or less than 3 cm in length, hence were considered very small in size.

The effects of $CaCO_3$ on mineral content of bell pepper are presented in table 3. The mineral content of the shoots was not significantly affected by Ca source except for Ca content. The greatest Ca percent was 0.87 which was observed in the 400 ppm $CaCO_3$ treated plants. The smallest value of 0.34 percent from the control was significantly lower than 0.87 percent from $CaCO_3$ treatment. The P, K and Mn were greatest at the control level whereas Ca, Mg and Zn were greatest in the 400 ppm $CaCO_3$ treatment.

Nonsignificant mineral contents were observed in the fruits for P, K, Ca, Mg, Mn and Zn (Table 4). The greater Ca values recorded for the shoot as compared to the fruit agrees with the findings of Beeson (5) who noted that the analysis of a great variety of cultivars of crop plants under many environmental conditions showed highest percent Ca in the foliage of legumes, tomato, tobacco, and other dicotyledonous plants.

Table 3.

Effects of $CaCO_3$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Tissue concentration (%) shoot					
	P	K	Ca	Mg	Mn	Zn
0	0.49	4.60	0.34	0.51	0.094	0.0059
400	0.34	4.15	0.87	0.53	0.072	0.0062
Average	0.42	4.38	0.61	0.52	0.083	0.0061
$LSD_{.05}$	NS	NS	0.34	NS	NS	NS

Table 4.

Effects of $CaCO_3$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Tissue concentration (%) fruit					
	P	K	Ca	Mg	Mn	Zn
0	0.36	2.50	0.10	0.16	0.0063	0.0054
400	0.31	2.60	0.11	0.17	0.0088	0.0054
Average	0.34	2.55	0.11	0.17	0.0076	0.0054
$LSD_{.05}$	NS	NS	NS	NS	NS	NS

The effects of $Ca(NO_3)_2$ on plant height, plant width, number of branches, number of flowers, fresh weight of shoot and yield of greenhouse grown bell pepper are presented in table 5. Plant width, number of flowers, number of branches, shoot fresh weight and yield were not significantly affected by Ca treatment. Plant height was significantly affected by Ca source. The greatest plant height was 16.80 cm in the control plants. The smallest plant height was 13.40 which was observed in the 400 ppm $Ca(NO_3)_2$ treated plants. Higher soil pH range of 4.8 to 5.1 recorded for the control as compared to 4.7 to 5.0 noted for the $Ca(NO_3)_2$ treated plants could have favored greater plant height observed for the control plants. However, these pH ranges were lower than 5.2 to 6.2 recommended for sweet pepper production in Cahaba Silt Loam soil (38). Because low pH depressed availability of essential macronutrients to the plants, reproductive growth was initiated while the plants were still shorter than 10 cm, causing stunted growth of these plants. Clarkson (14) indicated that a high Al ion concentration is the common cause of failure of agricultural crops in acid soils. Phsiologically, a high Al ion concentration in the free space on the root surface may prevent phosphate uptake and may interfere with sugar phosphorylation. Jones and Lunt (39) reported that the normal development of corn roots require only 3 to 10 μM Ca ion in the soil solutions in the absence of other ions. Healthy roots were found to contain 0.007 percent Ca on dry

Table 5.

Effects of $Ca(NO_3)_2$ on growth, flowering, shoot fresh weight and yield of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches/palnt	Number of flowers/plant	Fresh weight shoot (gm)	yield (gm)
0	16.80	18.68	5.50	7.00	11.75	7.00
400	13.40	18.13	6.25	6.00	11.43	15.80
Average	15.10	18.41	5.88	7.00	11.59	11.40
C.V., %	12.18	10.23	17.68	10.91	19.00	22.02
$LSD_{.05}$	2.84	NS	NS	NS	NS	NS

weight basis.

The effects of $Ca(NO_3)_2$ on fruit length, percent dry matter of shoot and fruit, fruit maturity and fruit size of bell pepper are shown in table 6. Fruit length and percent dry matter of shoot were not significantly affected by Ca treatment. Fruit dry matter percentages ranged from 3.75, observed in the control treatment to 6.53 in the 400 ppm Ca $(NO_3)_2$ treated plants. The 6.53% recorded in the 400 ppm Ca $(NO_3)_2$ treatment was significantly greater than 3.75% from the control treatment. Fruits from both the control and 400 ppm Ca $(NO_3)_2$ treated plants were immature at harvest. However, these had to be harvested since the duration of the experiment was limited to 80 days from the transplanting date as was recommended by Cannon and Koske (9) for bell pepper production in Louisiana. Fruits from the $Ca(NO_3)_2$ treated plants were less than 4 cm but greater than 3 cm in length, hence were considered small. Those from the control treated plants were 3 cm or less in length, hence were considered very small in size.

The effects of $Ca(NO_3)_2$ on mineral content of bell pepper are presented in table 7. The mineral contents of the shoots were not significantly affected by Ca treatment. The P, K and Mn were greatest at the control level whereas Ca, Mg and Zn were greatest when 400 ppm $Ca(NO_3)_2$ was applied.

Nonsignificant mineral contents were also observed in the fruits (Table 8).

Table 6.

Effects of $Ca(NO_3)_2$ on fruit length, percent dry matter of shoot and fruit, fruit maturity and fruit size of greenhouse grown bell pepper (<u>Capsicum</u> <u>annuum</u> L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Fruit length (cm)	Percent D.M. shoot	Percent D.M. fruit	Fruit maturity	Fruit size
0	2.55	15.13	3.75	I[Y]	VS[Z]
400	3.65	14.08	6.53	I	S
Average	3.10	14.61	5.14	–	–
C.V.,%	13.34	11.32	11.38	–	–
$LSD_{.05}$	NS	NS	2.04	–	–

[Y] I = Immature

[Z] VS = Very small, S = Small

Table 7.

Effects of $Ca(NO_3)_2$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Tissue concentration (%) shoot					
	P	K	Ca	Mg	Mn	Zn
0	0.49	4.60	0.34	0.51	0.094	0.006
400	0.47	4.10	0.43	0.58	0.073	0.009
Average	0.48	4.35	0.39	0.55	0.084	0.008
$LSD_{.05}$	NS	NS	NS	NS	NS	NS

Table 8.

Effects of $Ca(NO_3)_2$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Tissue concentration (%) fruit					
	P	K	Ca	Mg	Mn	Zn
0	0.36	2.50	0.10	0.16	0.0063	0.0054
400	0.45	2.80	0.17	0.23	0.0054	0.0052
Average	0.41	2.65	0.14	0.20	0.0059	0.0053
$LSD_{.05}$	NS	NS	NS	NS	NS	NS

The effects of $CaSO_4$ on plant height, plant width, number of branches, number of flowers, fresh weight of shoot and yield of greenhouse grown bell pepper are presented in table 9. The number of branches, number of flowers and yield were not significantly affected by Ca treatment. Plant height was significantly affected by Ca source. The greatest plant height was 16.80 which was observed in the control treated plants. The smallest value of 13.43 was noted for the $CaSO_4$ treated plants. Coleman and Mehlich (15) noted that when gypsum or $CaSO_4$ was added to acid soils, soil pH was depressed and Al and Mn concentration of the solution increased, sometimes to levels toxic to plants. Ragland and Coleman (70) reported that adding a neutral Ca salt, such as $CaSO_4$ or $CaCl_2$, may aggravate the harmful effect of acidity by increasing uptake of Mn and Al. The greatest plant width was 18.68 which was observed in the control treatment. The smallest value of 15.50 was recorded for the 400 ppm $CaSO_4$ treated plants. The low value recorded for $CaSO_4$ treated plants could suggest that more leaves were lost in $CaSO_4$ treatments because of the greater toxic effects of both Al and Mn, favored by more depressed pH. The pH range for $CaSO_4$ treatments was 4.5 to 5.0 as compared to 4.8 to 5.1 noted for the control treatments. The greatest shoot fresh weight recorded

Table 9.

Effects of $CaSO_4$ on growth, flowering, shoot fresh weight and yield of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches/plant	Number of flowers/plant	Fresh weight shoot (gm)	yield (gm)
0	16.80	18.68	5.50	7.00	11.75	7.00
400	13.43	15.50	6.75	6.00	5.63	12.70
Average	15.12	17.09	6.13	6.50	8.69	9.85
C.V.,%	12.18	10.23	17.68	10.91	19.00	22.02
$LSD_{.05}$	2.84	2.83	NS	NS	3.62	NS

was 11.75 g which was observed in the control treatments. The $CaSO_4$ treated plants had the lowest shoot fresh weight of 5.63 g.

The effects of $CaSO_4$ on fruit length, percent dry matter of shoot and fruit, fruit maturity and fruit size of bell pepper are shown in table 10. The fruit length and percent dry matter of shoot were not significantly affected by this Ca treatment. The effects of $CaSO_4$ on fruit dry matter percentages were significant. Fruit dry matter percentages ranged from 3.75 observed in the control treatments to 7.8 noted for the 400 ppm $CaSO_4$ treated plants. The 7.8% noted for the 400 ppm $CaSO_4$ treated plants was significantly greater than 3.75% observed in the control treatments. Fruits from both the control and the 400 ppm $CaSO_4$ treatments were immature at harvest. The fruit sizes were very small, and small for the control and 400 ppm $CaSO_4$ treated plants, respectively. Two very small fruits with blossom-end rot were also harvested from the control plants. The incidence of blossom-end rot could be due to Ca deficiency or excess of soluble salts.

The effects of $CaSO_4$ on mineral content of bell pepper are presented in table 11. The mineral content of the shoots were not significantly affected by Ca treatment. The P, Ca, Mg, Mn and Zn contents were greatest in the 400 ppm $CaSO_4$ treatments. The K content of the shoots was greatest at the control level.

Table 10.

Effects of $CaSO_4$ on fruit length, percent dry matter of shoot and fruit, fruit maturity, and fruit size of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Fruit length (cm)	Percent D.M. shoot	Percent D.M. fruit	Fruit maturity	Fruit size
0	2.55	15.13	3.75	I[Y]	VS[Z]
400	3.90	14.27	7.80	I	S
Average	3.23	14.70	5.78	-	-
C.V.,%	11.34	11.32	11.38	-	-
$LSD_{.05}$	NS	NS	2.08	-	-

[Y]I = Immature

[Z]VS = Very small, S = Small

Table 11.

Effects of $CaSO_4$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Tissue concentration (%) shoot					
	P	K	Ca	Mg	Mn	Zn
0	0.49	4.60	0.34	0.51	0.094	0.006
400	0.64	3.10	0.57	0.81	0.103	0.007
Average	0.57	3.85	0.46	0.66	0.099	0.007
$LSD_{.05}$	NS	NS	NS	NS	NS	NS

The effects of $CaSO_4$ on mineral content of fruits of bell pepper are shown in table 12. Calcium source had no significant effect on P, K, Ca, Mg, Mn and Zn. The macronutrients were greatest in the 400 ppm $CaSO_4$ treated plants.

Greenhouse Source Experiment Summer 1982)

This experiment was conducted to determine the effects of sources of Ca, soil pH and season on bell pepper growth, yield and mineral content. Unlike the preliminary study, additional growth and yield characteristics of bell pepper were studied. The effects of $CaCO_3$ on plant height, plant width, number of branches, leaf area, leaf abscission, number of flowers, yield and fruit length are presented in table 13. Plant height, plant width, number of branches and leaf area were not significantly affected by Ca source. Calcium treatment however, significantly affected leaf abscission, number of flowers, yield and fruit length. The greatest number of leaves to absciss was 25.50 per plant which was observed in the control. The smallest leaf abscission value was 18.18 noted in the 400 ppm $CaCO_3$ treated plants. It may be suggested that low Ca was responsible for the yellowing of lower leaves and curling of the younger leaves, leading to higher leaf abscission in the control plants. The number of flowers was greatest in the 400 ppm $CaCO_3$ treated plants. The smallest number of flowers was 10.88 in the control treatment. This value was significantly lower than 15.88 observed in the 400 ppm $CaCO_3$ treatments. The greatest

Table 12.

Effects of $CaSO_4$ on mineral content of greenhouse grown bell pepper (*Capsium annuum* L.) cv. Keystone Resistant Giant #4 (Spring, 1982).

Ca treatment (ppm)	Tissue concentration (%) fruit					
	P	K	Ca	Mg	Mn	Zn
0	0.36	2.50	0.10	0.16	0.0063	0.0054
400	0.42	3.68	0.15	0.20	0.0130	0.0043
Average	0.39	3.09	0.13	0.18	0.0100	0.0049
$LSD_{.05}$	NS	NS	NS	NS	NS	NS

Table 13.

Effects of $CaCO_3$ on plant height, plant width, number of branches, average leaf area, leaf abscission, number of flowers, yield and fruit length of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches	Av. leaf area (sq cm)	Leaf abscission per plant	Number of flowers/plant	Yield per plant (gm)	Fruit length (cm)
0	40.38	28.73	6.25	51.62	25.50	10.88	10.65	3.22
400	40.38	25.81	6.50	45.34	18.18	15.88	22.48	5.38
Average	40.38	27.27	6.38	48.48	21.84	13.38	16.57	4.30
C.V.,%	9.25	9.27	18.69	12.90	17.42	19.17	7.86	13.09
$LSD_{.05}$	NS	NS	NS	NS	5.34	3.53	3.66	0.97

yield recorded was 22.48 g which was observed in the 400 ppm $CaCO_3$ treatments. The smallest yield recorded was 10.65 g noted in the control. It should be noted that although the control pepper plants had the same plant heights as the Ca treatments but were greater in plant width. The greatest fruit length was 5.38, which was observed in the 400 ppm $CaCO_3$ treatments. The lowest fruit length value was 3.22 cm in the control plants. Chiba (13) noted that a soil pH of 7.2 was considerably better for pepper plants growth than a higher pH. He added that pepper plants grown on a soil pH of 6.5 had a greater plant height, most uniform growth, highest root weight, production and more mineral uptake.

The effects of $CaCO_3$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of the stem, leaf, and fruit are shown in table 14. The number of lobes, bud drop, fruit abscission and percent dry matter of stems were not significantly affected by Ca source. The effects of $CaCO_3$ on fruit diameter, percent by matter of leaves and fruits were significant. The greatest fruit diameter was 3.54 cm in the 400 ppm $CaCO_3$ treated plants. The lowest fruit diameter was 2.63 cm in the control treatments. This value was significantly lower than 3.54 noted for 400 ppm $CaCO_3$ treated plants. It was observed that fruit diameter, fruit length and yield were positively correlated with calcium

Table 14.

Effects of $CaCO_3$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Fruit diameter (cm)	Number of lobes	Bud drop per plant	Percent fruit abscission/plant	Fruit size	Fruit maturity	% D.M. stem	% D.M. leaf	% D.M. fruit
0	2.63	2.75	12.00	89.79	VS[Z]	I[Y]	16.18	14.79	11.52
400	3.54	3.10	11.25	90.91	M	MT	14.86	11.11	7.63
Average	3.09	2.93	11.63	90.35	-	-	15.52	12.95	9.58
C.V.,%	12.18	7.68	12.78	3.49	-	-	15.27	12.40	19.15
$LSD_{.05}$	0.61	NS	NS	NS	-	-	NS	2.49	2.87

[Y]I = Immature, MT = Mostly mature

[Z]VS = Very small, M = Medium

treatments. The greatest leaf dry matter percent was 14.79, which was observed in the control treatments. The smallest leaf dry matter percent was 11.11 in the 400 ppm $CaCO_3$ treatments. This value was significantly lower than 14.79 in the control treatments. The percent dry matter ranges of 14.86 to 16.18 and 11.11 to 14.79 observed in the stems and leaves respectively, agree with the findings of Epstein (22) who indicated that when fresh plant shoots are dried at 70^{o}C for 24 to 48 hours, the dry matter remaining will be roughly 10 to 20% of the initial fresh weight. Fruit dry matter percent was 11.52 in the control treatments. This was significantly greater than 7.63 which was recorded in the 400 ppm $CaCO_3$ treatment. The data indicated that on the average the stem had the greatest percent dry matter (15.52) then the leaf (12.95) and lastly the fruit (9.58). Fruits from the 400 ppm $CaCO_3$ treatments were over 4 cm, but less than 6 cm in length, hence were considered medium in size. Those from the control treatments were 3 cm or less, hence were considered very small in size. Verkerk (80) reported that a decrease in fruit size of tomato fruits was associated with increased number of fruits developing on the plants. It is possible that under this condition competitive limitations on the growth rates of the fruits occurred because the larger number of fruits depended on the nutrient supplies of the plant. Most of the fruits harvested from the 400 ppm $CaCO_3$ treated plants were mature at harvest. The fruits were firm and crisp when touched as compared to fruits from the control. The firm and crisp nature of the matured fruits could be due to formation of calcium pectate paste in the middle lamellar of adjoining tissue. Burstron (7) indicated that the formation of Ca pectate increased the rigidity of the cell wall thereby increasing the resistance to infections.

The effects of $CaCO_3$ source on the mineral cotent of the stem are noted in table 15. The effects of Ca source on K, Ca, Mg and Fe were not significant. Calcium source had significant effects on P, Mn and Zn content in the stem. The greatest mineral contents were 1.30, 0.86, 0.48 and 0.42 recorded for P, K, Ca and Mg, respectively, in the 400 ppm $CaCO_3$ treated plants. The Mn and Zn were greatest at the control levels.

The effects of $CaCO_3$ source on the mineral content of the leaf are presented in table 16. The effects of Ca source were nonsignificant on the amounts of K, Zn and Fe in the leaves. The greatest amount of minerals were 3.55,1.18, 0.68 and 0.24 recorded for P, K, Ca and Mg, respectively, in the 400 ppm $CaCO_3$ treated plants. The greatest values of Mn, Zn, and Fe were 0.15, 0.015 and 0.039, respectively, in the control plants.

The effects of $CaCO_3$ source on the mineral content of the fruit of bell pepper are shown in table 17. The effects were not significant except for P and Mn contents. The greatest amount of P was 2.32, which was observed in the

Table 15.

Effects of $CaCO_3$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Tissue concentration (%) stem						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.65	0.64	0.24	0.28	0.100	0.0062	0.0094
400	1.30	0.86	0.48	0.42	0.029	0.0018	0.0110
Average	0.98	0.75	0.36	0.35	0.065	0.0040	0.0100
$LSD_{.05}$	0.37	NS	NS	NS	0.020	0.0036	NS

Table 16.

Effects of $CaCO_3$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Tissue concentration (%) leaf						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.66	1.17	0.26	0.13	0.150	0.015	0.039
400	3.55	1.18	0.68	0.24	0.072	0.009	0.015
Average	2.11	1.18	0.47	0.19	0.110	0.012	0.027
$LSD_{.05}$	0.91	NS	0.20	0.09	0.06	NS	NS

Table 17.

Effects of $CaCO_3$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Tissue concentration (%) fruit						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.44	0.57	0.100	0.17	0.032	0.0024	0.0052
400	2.32	0.71	0.093	0.15	0.007	0.0020	0.0050
Average	1.38	0.64	0.097	0.16	0.020	0.0022	0.0051
$LSD_{.05}$	0.31	NS	NS	NS	0.010	NS	NS

400 ppm $CaCO_3$ treatments whereas Mn had its greatest value of 0.032 in the control plants.

The effects of $Ca(NO_3)_2$ on plant height, plant width, number of branches, leaf area, leaf abscission, number of flowers, yield and fruit length of greenhouse grown bell pepper are presented in table 18. Calcium source had no significant effect on the number of branches, leaf area, number of flowers, yield and fruit length. Treatments had significant effects on plant height, plant width and leaf abscission. The greatest plant height was 40.38 cm, which was observed in the control plants. The smallest plant height was 29.00 in the $Ca(NO_3)_2$ treated plants. The higher pH range of 5.5 to 5.7 noted for the control could have favored greater plant height and width. The greatest plant width was 28.73 cm in the control plants. The smallest width was 22.63 cm in the 400 ppm $Ca(NO_3)_2$ treated plants. This value was significantly lower than 28.73 cm recorded in the control plants. The greatest number of leaves to absciss was 25.50 while only 13.88 abscissed in the 400 ppm $Ca(NO_3)_2$ treated plants.

The effects of $Ca(NO_3)_2$ source on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter are presented in table 19. The effects were not significant for fruit diameter, number of lobes, fruit abscission, percent dry matter in the leaves and fruits. Calcium source had significant effects

Table 18.

Effects of $Ca(NO_3)_2$ on plant height, plant width, number of branches, average leaf area, leaf abscission, number of flowers, yield and fruit length of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches	Av. leaf area (sq cm)	Leaf abscission per plant	Number of flowers/plant	Yield per plant (gm)	Fruit length (cm)
0	40.38	28.73	6.25	51.62	25.50	10.88	10.65	3.22
400	29.00	22.63	6.50	49.24	13.88	8.88	14.00	3.86
Average	34.69	25.68	6.38	50.43	19.69	9.88	12.32	3.54
C.V.,%	9.25	9.27	18.69	12.90	17.42	19.17	7.86	13.09
$LSD_{.05}$	5.11	3.69	NS	NS	5.34	NS	NS	NS

Table 19.

Effects of $Ca(NO_3)_2$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Fruit diameter (cm)	Number of lobes	Bud drop per plant	Percent fruit abscission/plant	Fruit size	Fruit maturity	% D.M. stem	% D.M. leaf	% D.M. fruit
0	2.63	2.75	12.00	89.79	VS^{Z}	I^{Y}	16.18	14.79	11.52
400	2.79	3.00	7.25	88.59	VS	I	12.71	15.10	10.30
Average	2.71	2.88	9.63	89.19	-	-	14.45	14.95	10.91
C.V.,%	12.18	7.68	12.78	3.49	-	-	15.27	12.40	19.15
LSD$_{.05}$	NS	NS	1.82	NS	-	-	3.41	NS	NS

^{Y}I = Immature

^{Z}VS = Very small

on bud drop and percent dry matter in the stems. The greatest bud drop recorded was 12.00 in the control. Loss of buds could be associated with the "die back" of the young buds due to immobility of Ca in plants. Sorokin and Sommer (76) reported that omission of Ca from a complete nutrient medium caused rapid degeneration of the apical cells of *Pisum satiuum*. The lower bud drop in the $Ca(NO_3)_2$ treated plants could be a result of fewer buds formed due to a low soil pH or deficiency of an essential macronutrient. The greatest stem dry matter percentage was 16.18 in the control plants. The lower stem dry matter percentage was 12.71 which was recorded in the 400 ppm $Ca(NO_3)_2$ treated plants. This value was significantly smaller than 16.18% observed in the control treatment. Fruit sizes were 3 cm or less for both the control and the 400 ppm $Ca(NO_3)_2$ treated plants, hence were considered very small. The maturity level noted indicated that fruits from both treatments were immature at harvest.

The effects of $Ca(NO_3)_2$ on mineral content of the stems of bell pepper are presented in table 20. The effects of Ca source on P, K and Fe content of the stems were not significant. However, significant effects were observed for Ca, Mg, Mn and Zn. The greatest Ca and Mg contents of 0.85 and 0.50, respectively, were observed in the 400 ppm $Ca(NO_3)_2$ treated plants. The Mn content was significantly greater in the

Table 20.

Effects of $Ca(NO_3)_2$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Tissue concentration (%) stem						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.65	0.64	0.24	0.28	0.100	0.0062	0.0094
400	0.44	0.55	0.85	0.50	0.056	0.0150	0.0180
Average	0.55	0.60	0.55	0.39	0.078	0.0110	0.0140
$LSD_{.05}$	NS	NS	0.45	0.17	0.020	0.004	NS

control treated plants, whereas Zn and Fe were greater in the 400 ppm $Ca(NO_3)_2$ treatments.

The effects of $Ca(NO_3)_2$ on mineral content of the leaves of bell pepper are presented in table 21. The P, Mn and Zn contents were not significantly affected by Ca source. The K, Ca, Mg and Fe contents of the leaves were significantly affected by Ca source. The 0.66, 0.26 and 0.13 percentages recorded in the control treatments for P, Ca and Mg, respectively were significantly lower than the 0.77, 0.79 and 0.27 percentages observed, respectively, for P, Ca and Mg in the 400 ppm $Ca(NO_3)_2$ treated plants. The Mn, Zn and Fe contents were greater in the control treated plants.

The effects of $Ca(NO_3)_2$ on mineral contents of the fruits of bell pepper are shown in table 22. The K , Ca, Mg, Zn and Fe contents were not significantly affected by Ca source. Calcium nitrate treatments had significant effects on P and Mn in the fruit. The nonconsistent distribution of these elements could be due to varied levels of fruit maturity at harvest.

The effects of $CaSO_4$ on plant height, plant width, number of branches, average leaf area, leaf abscission, number of flowers, yield and fruit length of greenhouse grown bell pepper are presented in table 23. Plant width, number of branches, leaf abscission and number of flowers were not significantly affected by Ca source. Plant height, leaf area, yield and fruit length were significantly affected by

Table 21.

Effects of $Ca(NO_3)_2$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Tissue concentration (%) leaf						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.66	1.17	0.26	0.13	0.15	0.015	0.039
400	0.77	0.86	0.79	0.27	0.11	0.009	0.012
Average	0.72	1.02	0.53	0.20	0.13	0.012	0.026
$LSD_{.05}$	NS	0.27	0.20	0.09	NS	NS	0.020

Table 22.

Effects of $Ca(NO_3)_2$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Tissue concentration (%) fruit						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.44	0.57	0.10	0.17	0.032	0.0024	0.0052
400	0.83	0.54	0.11	0.12	0.012	0.0030	0.0070
Average	0.64	0.56	0.11	0.15	0.022	0.0027	0.0061
$LSD_{.05}$	0.31	NS	NS	NS	0.01	NS	NS

Table 23.

Effects of $CaSO_4$ on plant height,plant width, number of branches, average leaf area, leaf abscission, number of flowers, yield and fruit length of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches	Av. leaf area (sq cm)	Leaf abscission per plant	Number of flowers/plant	Yield per plant (gm)	Fruit length (cm)
0	40.38	28.73	6.25	51.62	25.50	10.88	10.65	3.22
400	33.56	26.00	6.25	36.98	21.38	12.25	15.42	5.08
Average	36.97	27.37	6.25	44.30	23.44	11.57	13.04	4.15
C.V.,%	9.25	9.27	18.69	12.90	17.42	19.17	7.86	13.09
$LSD_{.05}$	5.11	NS	NS	9.10	NS	NS	3.64	0.91

Ca source. The greatest plant height recorded was 40.38 cm which was in the control plants. The smallest height was 33.56 cm in the 400 ppm $CaSO_4$ treated plants. Ragland and Coleman (76) reported that adding a neutral calcium salt, such as $CaSO_4$ or $CaCl_2$ may aggravate the harmful effect of acidity by increasing uptake of Mn and Al. The greatest leaf area was 51.62 sq cm which was recorded in the control treatment. The smallest leaf area was 36.98 sq cm, in the 400 ppm $CaSO_4$ treated plants. This was significantly lower than 51.62 sq cm observed in the control plants. The greatest yield recorded was 15.42 g which was observed in the 400 ppm $CaSO_4$ treated plants. The smallest yield was 10.65 g, in the control plants. This value was significantly lower than 15.42 g recorded in the 400 ppm $CaSO_4$ treated plants. Low yield could be due to limited fruit set as a result of limited pollination in the greenhouse, nutrient uptake and precocious abscission of flowers and newly set fruits. The greatest fruit length recorded was 5.08 cm which was in the 400 ppm treatments. The smallest fruit length was 3.22, in the control.

The effects of $CaSO_4$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of stems, leaves and fruits are presented in table 24. Fruit diameter, number of lobes, fruit abscission, percent dry matter in the stems and fruits were not significantly affected by Ca treatments. Bud drop and percent

Table 24.

Effects of $CaSO_4$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Fruit diameter (cm)	Number of lobes	Bud drop per plant	percent fruit abscission/plant	Fruit size	Fruit maturity	% D.M. stem	% D.M. leaf	% D.M. fruit
0	2.63	2.75	12.00	89.79	VS[Z]	I[Y]	16.18	14.79	11.52
400	2.89	2.79	14.38	91.02	M	MT	14.45	11.10	9.41
Average	2.76	2.77	13.19	90.41	-	-	15.32	12.95	10.47
C.V.,%	12.18	7.68	12.78	3.49	-	-	15.27	12.40	19.15
$LSD_{.05}$	NS	NS	1.82	NS	-	-	NS	2.49	NS

[Y] I = Immature, MT = Mostly mature

[Z] VS = Very small, M = Medium

dry matter in the leaves were significantly affected by Ca treatments. The greatest bud drop per plant was 14.38 which was recorded in the 400 ppm treatments. The smallest bud drop was 12.00 in the control plants. The greatest leaf dry matter percentage was 14.79 which was in the control plants. The smallest leaf dry matter percentage was 11.10, in the $CaSO_4$ treatments.

The effects of $CaSO_4$ source on mineral content of stems of greenhouse grown bell pepper are shown in table 25. The effects of Ca source were significant for the P content of the stem. Nonsignificant variations were observed for K, Ca, Mg, Mn, Zn and Fe. The greatest amount of P measured was 1.49 percent in the 400 ppm $CaSO_4$ treatments, whereas the smallest value of 0.65 percent was noted in the control.

The effects of $CaSO_4$ on mineral contents of the leaves of bell pepper are tabulated in table 26. The effects of Ca source were significant for P, Ca and Mg. Nonsignificant variations were observed for K, Mn, Zn and Fe. The greatest macronutrient contents were 3.19, 1.27, 0.56 and 0.26, recorded for P, K, Ca and Mg, respectively, in the 400 ppm $CaSO_4$ treated plants. Zinc and Fe had greatest values of 0.015 and 0.039, respectively, in the control plants.

The effects of $CaSO_4$ on mineral contents of the fruits of bell pepper are shown in table 27. Calcium source had a significant effect for P and Mn. The inconsistent mineral distribution observed could be due to varied levels of

Table 25.

Effects of $CaSO_4$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Tissue concentration (%) stem						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.65	0.64	0.24	0.28	0.100	0.0062	0.0094
400	1.49	0.76	0.41	0.37	0.085	0.0060	0.0140
Average	1.07	0.70	0.33	0.33	0.093	0.0061	0.0120
$LSD_{.05}$	0.37	NS	NS	NS	NS	NS	NS

Table 26.

Effects of $CaSO_4$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Tissue concentration (%) leaf						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.66	1.17	0.26	0.13	0.15	0.015	0.039
400	3.19	1.27	0.56	0.26	0.17	0.013	0.029
Average	1.93	1.22	0.41	0.20	0.16	0.014	0.034
$LSD_{.05}$	0.91	NS	0.20	0.09	NS	NS	NS

Table 27.

Effects of $CaSO_4$ on mineral content of greenhouse grown bell peppers (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

Ca treatment (ppm)	Tissue concentration (%) fruit						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.44	0.57	0.10	0.17	0.032	0.0024	0.0052
400	2.00	0.61	0.08	0.16	0.016	0.0025	0.0050
Average	1.22	0.59	0.09	0.17	0.024	0.0025	0.0051
$LSD_{.05}$	0.94	NS	NS	NS	0.012	NS	NS

maturity noted among the fruits harvested.

Greenhouse Source Experiment (Fall 1982)

This experiment was conducted to determine the effects of sources of Ca, soil pH and season on bell pepper growth, Yield and mineral content. Growth and yield characteristics studied were similar to those in the summer 1982 experiment. The effects of $CaCO_3$ on plant height, plant width, number of branches, leaf area, leaf abscission, number of flowers, yield and fruit length are presented in table 28. Plant height, plant width, number of branches and number of flowers were not significantly affected by Ca treatments. Leaf area, leaf abscission, yield and fruit length were significantly affected by Ca treatments. The greatest leaf area recorded was 92.75 sq cm, which was observed in the 400 ppm $CaCO_3$ treated plants. The smallest leaf area was 55.24 sq cm in the control treatments. This value was significantly lower than the 92.75 sq cm, recorded in the 400 ppm $CaCO_3$ treatments. The better soil pH range (5.2 to 5.7) and leaf-area ratio could have given rise to higher quality plant growth observed in the 400 ppm $CaCO_3$ treated plants. The greatest leaf abscission was 7.88 which was in the control plants. The smallest leaf abscission value was 5.75, in the 400 ppm $CaCO_3$ treated plants. This was significantly lower than 7.88 noted in the control plants. The greatest yield recorded was 45.99 g which was in the 400 ppm treatments. Better quality plant growth could be responsible for greater yield observed

Table 28.

Effects of $CaCO_3$ on plant height, plant width, number of branches, average leaf area, leaf abscission, number of flowers, yield and fruit length of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches	Av. leaf area (sq cm)	Leaf abscission per plant	Number of flowers/plant	Yield per plant (gm)	Fruit length (cm)
0	25.18	26.23	5.00	55.24	7.88	8.75	20.04	5.14
400	25.60	30.18	6.00	92.75	5.75	11.63	45.99	6.70
Average	25.39	28.21	5.50	74.00	6.82	10.19	33.02	5.92
C.V.,%	13.24	11.00	9.40	10.55	16.28	18.81	16.94	10.17
$LSD_{.05}$	NS	NS	NS	9.88	1.15	NS	22.27	0.83

in the 400 ppm $CaCO_3$ treatment. Fruit length was significantly greater in the 400 ppm $CaCO_3$ treated plants. The smallest value of 5.14 cm in the control treatments was significantly lower than 6.70 cm observed in the 400 ppm treatments. This fruit length range of 5.14 to 6.70 cm was smaller than 8.89 to 11.43 cm range reported by Montelaro et al. (54).

The effects of $CaCO_3$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of bell peper are presented in table 29. Number of lobes, fruit abscission, percent dry matter in the stems and fruits were not significantly affected by Ca treatments. Significant effects were observed for fruit diameter, bud drop and percent dry matter of leaves. The greatest fruit diameter was 4.69 cm, which was observed in the 400 ppm $CaCO_3$ treatments. The smallest fruit diameter was 3.24 in the control plants. The greatest bud drop per plant recorded was 7.13 which was observed in the control treatments. The smallest bud drop per plant was 4.75 in the 400 ppm $CaCO_3$ treated plants. The greatest leaf dry matter percentage was 11.77 which was observed in the 400 ppm $CaCO_3$ treated plants. The smallest leaf dry matter percentage was 9.77 in the control plants. This was significantly lower than 11.77 noted in the 400 ppm $CaCO_3$ treated plants. Fruits from the control were greater than 4 cm but less than 6 cm in length, hence were considered medium in size. Those from the $CaCO_3$

Table 29.

Effects of $CaCO_3$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Fruit diameter (cm)	Number of lobes	Bud drop per plant	Percent fruit abscission/plant	Fruit size	Fruit maturity	% D.M. stem	% D.M. leaf	% D.M. fruit
0	3.24	3.25	7.13	83.01	M[Z]	MI[Y]	14.38	9.77	6.25
400	4.69	3.38	4.75	88.98	L	MT	16.22	11.77	6.81
Average	3.97	3.32	5.94	86.00	–	–	15.30	10.77	6.53
C.V.,%	6.97	11.93	17.17	9.12	–	–	17.58	10.27	10.49
$LSD_{.05}$	0.38	NS	1.45	NS	–	–	NS	1.94	NS

[Y]MI = Mostly immature

[Z]M = Medium, L = large

treatments were 6 cm or greater in length, hence were considered large. Fruits harvested from $CaCO_3$ treated plants were mostly mature at harvest, whereas those from the control were mostly immature.

The effects of $CaCO_3$ on mineral content of bell pepper are presented in table 30. The effects of $CaCO_3$ on the mineral contents of the stems were not significant for all elements except the Mg content. The greatest P and K contents of 0.07 and 4.85, respectively, were observed in the control plants. The greatest Ca and Mg contents of 1.36 and 0.55, respectively, were observed in the 400 ppm $CaCO_3$ treated plants. Manganese was uniform for both treatments, with a value of 0.034 reported in each case. The Fe and Zn contents were greater in 400 ppm $CaCO_3$ treatments.

The effects of $CaCO_3$ on mineral content of the leaves of bell pepper are shown in table 31. The treatments had significant effects on the Ca and Zn contents. The greatest P and K contents of 0.29 and 8.18, respectively were observed in the control plants. The greatest Ca and Mg contents of 3.08 and 0.88, respectively, were observed in the 400 ppm $CaCO_3$ treated plants. The Mn, Zn and Fe contents were greater in the control plants. Their values were 0.16, 0.018 and 0.026, respectively.

The effects of $CaCO_3$ on mineral content of the fruits of bell pepper are presented in table 32. Fruits from the Ca treatments were significantly higher in P, K and Ca in

Table 30.

Effects of $CaCO_3$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Tissue concentration (%) stem						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.07	4.85	0.63	0.40	0.034	0.0041	0.012
400	0.06	3.79	1.36	0.55	0.034	0.0050	0.013
Average	0.07	4.32	1.00	0.48	0.034	0.0050	0.013
$LSD_{.05}$	NS	NS	NS	0.04	NS	NS	NS

Table 31.

Effects of $CaCO_3$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Tissue concentration (%) leaf						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.29	8.18	1.50	0.81	0.16	0.018	0.026
400	0.28	7.18	3.08	0.88	0.10	0.011	0.021
Average	0.29	7.68	2.29	0.85	0.13	0.015	0.024
$LSD_{.05}$	NS	NS	0.41	NS	NS	0.006	NS

Table 32.

Effects of $CaCO_3$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Tissue concentration (%) fruit						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.36	3.06	0.12	0.21	0.011	0.005	0.008
400	0.43	3.39	0.30	0.21	0.004	0.004	0.008
Average	0.40	3.23	0.21	0.21	0.008	0.005	0.008
$LSD_{.05}$	0.04	0.31	0.03	NS	NS	NS	NS

all cases, whereas Mn and Zn were greater in the control treatments. Both Mg and Fe were equally distributed under each treatment.

The effects of $Ca(NO_3)_2$ on plant height, plant width, number of branches, average leaf area, leaf abscission, number of flowers, yield and fruit length of bell pepper are shown in table 33. Number of branches and yield were not significantly affected by Ca source. Plant height, plant width, leaf area, leaf abscission, number of flowers and fruit length were significantly affected by Ca source. The greatest plant height was 25.18 cm which was observed in the control treatments. The smallest height was 13.35 cm in the 400 ppm $Ca(NO_3)_2$ treated plants. This was significantly smaller than 25.18 cm noted in the control treatments. The greatest plant width was 26.23 cm which was observed in the control treatments. The smallest width was 18.85 in the 400 ppm $Ca(NO_3)_2$ treated plants. The greatest average leaf area was 55.24 sq cm which was observed in the control treatments. The smallest leaf area was 42.73 in the 400 ppm $Ca(NO_3)_2$ treatments. The greatest leaf abscission per plant was 7.88 which was observed in the control treatments. The smallest leaf abscission was 1.88 in the $Ca(NO_3)_2$ treatments. The greatest number of flowers was 8.75 which was recorded in the control treated plants. The smallest number of flowers was 4.38 in the 400 ppm $Ca(NO_3)_2$ treatments. Calcium supply may be considered essential for flower production. The

Table 33.

Effects of $Ca(NO_3)_2$ on plant height, plant width, number of branches, average leaf area, leaf abscission, number of flowers, yield and fruit length of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches	Av. leaf area (sq cm)	Leaf abscission per plant	Number of flowers/plant	Yield per plant (gm)	Fruit length (cm)
0	25.18	26.23	5.00	55.24	7.88	8.75	20.04	5.14
400	13.35	18.85	4.50	42.73	1.88	4.38	10.33	4.08
Average	19.27	22.54	4.75	48.99	4.88	6.57	15.19	4.61
C.V.,%	13.24	11.00	9.40	10.55	16.28	18.81	16.94	10.17
$LSD_{.05}$	4.15	4.24	NS	9.88	1.15	2.30	NS	0.83

greatest fruit length was 5.14 cm in the control treatments. The smallest fruit length was 4.08 cm observed in the 400 ppm $Ca(NO_3)_2$ treated plants. The pH range of 4.7 to 4.9 and greater Ca availability could account for better plant growth and production in the control plants. The pH range for $Ca(NO_3)_2$ treatments was 3.8 to 4.0.

The effects of $Ca(NO_3)_2$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of bell pepper are shown in table 34. Number of lobes and fruit abscission were not significantly affected by Ca treatments. Fruit diameter, bud drop, and percent dry matter of stems, leaves and fruits were significantly affected by Ca treatments. The greatest fruit diameter was 3.24 cm which was observed in the control plants. The smallest fruit diameter was 2.67 cm, in the 400 ppm $Ca(NO_3)_2$ treated plants. The greatest bud drop was 7.13 which was observed in the control. The smallest bud drop per plant was 5.38 in the 400 ppm $Ca(NO_3)_2$ treated plants. High day temperatures and nutrient deficiency could account for bud drop. The greatest stem dry matter percentage was 21.84 which was in the 400 ppm $Ca(NO_3)_2$ treatment. The smallest stem dry matter percentage was 14.38 in the control treated plants. Leaf dry matter percentage of 15.67 was observed in the 400 ppm $Ca(NO_3)_2$ treated plants. The smallest leaf dry matter percentage was 9.77 in the control. Fruit dry matter percent was greater in the 400 ppm $Ca(NO_3)_2$ treatment.

Table 34.

Effects of $Ca(NO_3)_2$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant (Fall, 1982).

Ca treatment (ppm)	Fruit diameter (cm)	Number of lobes	Bud drop per plant	Percent fruit abscission/plant	Fruit size	Fruit maturity	% D.M. stem	% D.M. leaf	% D.M. fruit
0	3.24	3.25	7.13	83.01	M[Z]	I[Y]	14.38	9.77	6.25
400	2.67	3.25	5.38	76.98	S	I	21.84	15.67	10.17
Average	2.95	3.25	6.26	80.00	–	–	18.11	12.72	8.21
C.V.,%	6.97	11.93	17.17	9.12	–	–	17.58	10.27	10.49
$LSD_{.05}$	0.38	NS	1.45	NS	–	–	4.68	1.94	1.25

[Y] I = Immature

[Z] M = Medium, S = Small

The smallest fruit dry matter percentage was 6.25 in the control treatment. This was significantly smaller than 10.17 observed in the 400 ppm $Ca(NO_3)_2$ treatment. Fruit size was small in the 400 ppm $Ca(NO_3)_2$ treated plants, whereas medium size fruits were harvested from the control plants. Immature fruits were harvested from both treatments.

The effects of $Ca(NO_3)_2$ on mineral content of the stems of bell pepper are shown in table 35. No significant effects were noted for K, Ca, Mg, Mn, Zn and Fe contents. The P content was significantly affected by Ca source. The greatest P content was 0.1 observed in the 400 ppm Ca treatments.

The effects of $Ca(NO_3)_2$ on the mineral content of the leaves of bell pepper are presented in table 36. The treatments had significant effects on P, K, Ca and Zn. The Mg, Mn and Fe contents were not significantly affected by Ca source.

The effects of $Ca(NO_3)_2$ on mineral content of the fruits of bell pepper are noted in table 37. The P, Ca, Mg and Mn were significantly affected by Ca source. Nonsignificant effects were observed for K, Zn and Fe. Generally, the distributions of mineral nutrients of fruits under the $Ca(NO_3)_2$ treatments were not consistent, possibly due to the variations in their maturity at harvest.

The effects of $CaSO_4$ on plant height, plant width, number of branches, leaf area, leaf abscission, number of flowers, yield and fruit length of greenhouse grown bell pepper are

Table 35.

Effects of $Ca(NO_3)_2$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Tissue concentration (%) stem						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.07	4.85	0.63	0.40	0.034	0.0041	0.012
400	0.10	4.07	1.39	0.53	0.063	0.0080	0.017
Average	0.09	4.46	1.01	0.47	0.049	0.0060	0.015
$LSD_{.05}$	0.01	NS	NS	NS	NS	NS	NS

Table 36.

Effects of $Ca(NO_3)_2$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Tissue concentration (%) leaf						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.29	8.18	1.50	0.81	0.16	0.018	0.026
400	0.18	6.09	3.52	0.91	0.21	0.010	0.017
Average	0.24	7.14	2.51	0.86	0.19	0.014	0.022
$LSD_{.05}$	0.09	1.33	0.41	NS	NS	0.006	NS

Table 37.

Effects of $Ca(NO_3)_2$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Tissue concentration (%) fruit						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.36	3.06	0.12	0.21	0.011	0.005	0.008
400	0.23	2.89	0.43	0.17	0.017	0.005	0.008
Average	0.30	2.98	0.28	0.19	0.014	0.005	0.008
$LSD_{.05}$	0.04	NS	0.03	0.03	NS	NS	NS

presented in table 38. Plant width, number of branches, leaf area, yield and fruit length were not significantly affected by Ca treatments. Plant height, leaf abscission, and number of flowers were significantly affected by Ca treatments. The greatest plant height was 25.18 cm observed in the control plants. The smallest height was 18.28 cm in the 400 ppm $CaSO_4$ treated plants. Flowering which occurred while the plants were about 10 cm high could have contributed to the stunted nature of most of the plants. The stunted growths in turn could have been responsible for the plant width value for each treatment being greater than the corresponding plant height. The greatest leaf abscission was 7.88 which was in the control plants. The smallest leaf abscission per plant was 2.88 in the 400 ppm $CaSO_4$ treated plants. The greatest number of flowers per plant was 8.75 noted in the control plants. The smallest number of flowers per plant was 5.88 in the 400 ppm $CaSO_4$ treated plants.

The effects of $CaSO_4$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of bell pepper are presented in table 39. Number of lobes, fruit abscission and percent dry matter of stems were not significantly affected by Ca source. Fruit diameter, bud drop and percent dry matter of leaves and fruit were significantly affected by Ca source. The greatest fruit diameter was 3.73 cm in the 400 ppm $CaSO_4$ treated plants. The smallest fruit diameter was 3.24 cm in the control plants.

Table 38.

Effects of $CaSO_4$ on plant height,plant width, number of branches, average leaf area, leaf abscission, number of flowers,yield and fruit length of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches	Av. leaf area (sq cm)	Leaf abscission per plant	Number of flowers/plant	Yield per plant (gm)	Fruit length (cm)
0	25.18	26.23	5.00	55.24	7.88	8.75	20.04	5.14
400	18.28	24.93	5.63	52.36	2.88	5.88	22.10	5.36
Average	21.73	25.58	5.32	53.80	5.38	7.32	21.07	5.25
C.V.,%	13.24	11.00	9.40	10.55	16.28	18.81	16.94	10.17
$LSD_{.05}$	4.15	NS	NS	NS	1.15	2.30	NS	NS

Table 39.

Effects of $CaSO_4$ on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Fruit diameter (cm)	Number of lobes	Bud drop per plant	Percent fruit abscission/plant	Fruit size	Fruit maturity	% D.M. stem	% D.M. leaf	% D.M. fruit
0	3.24	3.25	7.13	83.01	M[Z]	MI[Y]	14.38	9.77	6.25
400	3.73	3.33	4.75	79.60	M	MI	16.70	11.74	7.60
Average	3.49	3.29	5.94	81.30	–	–	15.54	10.76	6.93
C.V.,%	6.97	11.93	17.17	9.12	–	–	17.58	10.27	10.49
$LSD_{.05}$	0.38	NS	1.45	NS			NS	1.94	1.24

[Y]MI = Mostly immature

[Z]M = Medium

The greatest bud drop was 7.13 observed in the control. The smallest bud drop was 4.75 in the 400 ppm $CaSO_4$ treated plants. Death of buds have also been associated with low carbonhydrate in plants, nutrient deficiency, severe-water stress and excessively high temperatures. The greatest leaf dry matter percentage was 11.74 observed in the 400 ppm $CaSO_4$ treated plants. The smallest leaf dry matter percentage was 9.77 in the control treatments. Fruit dry matter percent was 7.60 for the 400 ppm $CaSO_4$ treated plants, and 6.25 in the control. This value was significantly lower than 7.60 observed in the 400 ppm $CaSO_4$ treatments.

The effects of $CaSO_4$ on mineral contents of the stems of bell pepper are shown in table 40. Nutrient contents of stems were not significantly affected by Ca source. Calcium and Mg contents were higher in the 400 ppm $CaSO_4$ treatments. The values for these two elements were 0.97 and 0.47, respectively. The P was greater in the control treatment, whereas, K had a uniform value of 4.85 under both treatments. The Mn and Zn had greatest values of 0.066 and 0.088, respectively in the 400 ppm $CaSO_4$ treatments.

The effects of $CaSO_4$ on mineral content of the leaves of bell pepper are presented in table 41. Treatments had significant effects on Ca only. This element had a greatest value of 2.31 in the 400 ppm $CaSO_4$ treatments. The P, K and Mg contents were greater in the control plants. The Zn and Fe contents were also greater in the control plants. These

Table 40.

Effects of $CaSO_4$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Tissue concentration (%) stem						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.07	4.85	0.63	0.40	0.034	0.0041	0.012
400	0.05	4.85	0.97	0.47	0.066	0.0080	0.009
Average	0.06	4.85	0.80	0.44	0.050	0.0060	0.011
$LSD_{.05}$	NS	NS	NS	NS	NS	NS	NS

Table 41.

Effects of $CaSO_4$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Tissue concentration (%) leaf						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.29	8.18	1.50	0.81	0.16	0.018	0.026
400	0.20	7.34	2.31	0.80	0.31	0.016	0.020
Average	0.25	7.76	1.91	0.81	0.24	0.017	0.023
$LSD_{.05}$	NS	NS	0.41	NS	NS	NS	NS

values were 0.018 and 0.026 for Zn and Fe, respectively.

The effects of $CaSO_4$ on mineral content of the fruits of bell pepper are shown in table 42. The P, Ca and Mg content of the fruits were significantly affected by Ca source. The P and Mg contents were greater in the control plants. The values observed were 0.36 and 0.21, respectively. The K and Ca contents were greater in the 400 ppm $CaSO_4$ treated plants. These values were 3.27 and 0.33, respectively. The Mn content was greater in the 400 ppm $CaSO_4$ treated plants. Equal distribution of Zn was noted whereas Fe had the greatest value of 0.008 in the control plants.

Greenhouse Rate Experiment (Summer 1982)

This test was conducted to determine the effects of levels of $CaCO_3$ and soil pH on plant height, yield and other yield components of bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 grown in the greenhouse in the summer of 1982. The effects of levels of Ca on plant height, plant width, number of branches, average leaf area, leaf abscission, number of flowers, yield and fruit length are shown in table 43. Number of branches per plant was not significantly affected by Ca levels. The greatest plant height recorded was 53.69 cm which was observed by applying 1,500 ppm $CaCO_3$. The smallest plant height was 40.38 in the controls. Leonard and Martin (44) noted that plant height was influenced by environmental conditions. Matev and Stanchev (50) reported that plant growth and development was depressed by antagonism

Table 42.

Effects of $CaSO_4$ on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

Ca treatment (ppm)	Tissue concentration (%) fruit						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.36	3.06	0.12	0.21	0.011	0.005	0.008
400	0.25	3.27	0.33	0.17	0.019	0.005	0.007
Average	0.31	3.17	0.23	0.19	0.015	0.005	0.008
$LSD_{.05}$	0.04	NS	0.03	0.03	NS	NS	NS

Table 43.

Effects of levels of calcium on plant height, plant width, number of branches, average leaf area, leaf abscission, number of flowers, yield and fruit length of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

$CaCO_3$ treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches/plant	Av. leaf area (sq cm)	Leaf abscission per plant	Number of flowers/plant	Yield per plant (gm)	Fruit length (cm)
0	40.38 b[z]	28.73 b	6.25	51.62 b	25.50 a	10.88 c	10.65 d	3.22 d
500	45.69 ab	31.25 a	7.00	63.26 ab	27.65 a	23.38 b	23.00 c	4.07 c
1,000	50.13 a	31.63 a	7.25	61.66 ab	23.38 a	23.38 b	26.28 bc	5.42 a
1,500	53.69 a	31.38 a	7.63	70.12 a	25.00 a	30.25 a	27.83 b	4.69 b
2,00	46.69 ab	32.06 a	7.38	72.80 a	20.13 b	27.88 a	36.10 a	5.43 a
Average	47.32	31.01	7.30	63.89	24.33	23.15	24.77	4.57
C.V.,%	11.37	4.50	14.53	12.58	11.89	7.69	8.92	3.71
			NS					

[z] Means within columns followed by the same letter do not differ significantly at the 5% level as measured by Duncan's New Multiple Range Test.

between Ca^{+2}, Mg^{+2}, or Na^{+} and K^{+}. A general increase in plant height with increase in Ca level was also observed. This may suggest that liming materials carry plant nutrients. It may also indicate that a good soil pH is essental for plant growth and development. Chiba (13), noted that a pH of 7.2 was considerably better for Capsicum plant growth than a higher pH. He added that pepper plants grown on a soil pH of 6.5 had greater height, more uniform growth, higher root weight, production and a greater nutrient uptake. Singh and Nettles (74) reported that by increasing Ca levels applied to peppers from 0 to 1,000 lb per acre, plant height was significantly higher but yield was reduced. The application of 2,000 ppm $CaCO_3$ resulted in the greatest plant width value of 32.06 cm. The smallest plant width was 28.73 cm observed in the control treatments. This value was significantly lower than other values recorded. Miller (53) noted that pepper plants grown in low Ca solutions were stunted and had very dark green leaves. The greatest leaf area recorded was 72.80 sq cm which was observed in the 2,000 ppm $CaCO_3$ treatments. The smallest leaf area was 51.62 sq cm in the control. Average leaf area generally increased significantly with increase in Ca level. Singh and Sharma (75) reported that highly significant reduction in leaf area, fresh weight and dry matter were some of the Ca deficiency symptoms recorded in different plants. Leaf abscission was greatest in the control with a value of 25.50 recorded. The lowest value observed was 20.13 in the 2,000 ppm treatments. This was significantly less than all other values recorded. It may be suggested that low Ca level at low soil pH could cause yellowing of the younger leaves, leading to abscission. The dark green color of leaves from higher Ca levels may suggest that Ca is part of the chloroplast. The greatest number of flowers was 30.25 which was observed in the 1,500 ppm $CaCO_3$ treatments. The greatest value recorded was significantly greater than other values except for 27.88 flowers from the 2,000 ppm $CaCO_3$ treatments. The smallest number of flowers was 10.88 in the controls and this was significantly less than all other treatments. This would suggest that flower production in this experiment was favored by at least 500 ppm Ca and even more at 1,500 ppm calcium. The greatest yield of 36.10 g was recorded in the 2,000 ppm Ca treatments. The smallest yield was 10.65 g in the control treatments. This value was significantly lower than all other values recorded. Yield generally increased with increase in Ca levels and pH. Fiskell (25) indicated that soil calcium supply is correlated very positively with the yield of U.S. grade A potatoes. It may be said that the significant factor in determining yield is the amount of active Ca in the soil. Leopold and Kriedemann (45) reported that yield is influenced by greater fluctuation between day and night temperatures. Fruits with greatest length were 5.43 cm in the 2,000 ppm Ca treatments. Fruits from the control treatments had the smallest length of 3.22 cm and this value was significantly lower than other values. The fruit length range of 3.22 to 5.43 cm is smaller than 8.89 to 11.43 cm range reported by Montelaro et al. (54).

The effects of levels of Ca on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, maturity and percent dry matter are noted in table 44. Number of lobes, fruit abscission and percent dry matter were unaffected by treatments. Calcium levels had significant effects on fruit diameter and bud drop. The largest fruit diameter observed was 4.04 cm in the 2,000 ppm Ca treatments. The smallest diameter value was 2.63 cm in the controls. This value was significantly lower than 4.04 and 3.62 cm recorded for 2,000 and 1,000 ppm Ca treatments. Fruit diameter was highly correlated with fruit length as indicated by Montelaro et al. (54). The greatest bud drop recorded was 18.25 which was observed in the 500 and 1,500 ppm Ca levels. The lowest bud drop value was 12.00 reported for the controls. This value was significantly lower than other values recorded. Bud drop data were not consistent. However, it was observed that the extent of bud drop depended on the initial number of buds formed. Bud drop could have been increased by high temperature and low humidity during the test period. Nightingale et al. (56) observed that Ca deficient plants had dead terminal buds, while their stems near the terminal were spotted with dead areas. Fruits from the control were 3 cm or less in

Table 44.

Effects of levels of calcium on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

$CaCO_3$ treatment (ppm)	Fruit diameter (cm)	Number of lobes	Bud drop per plant	Percent fruit abscission/plant	Fruit size	Fruit maturity	% D.M. stem	% D.M. leaf	% D.M. fruit
0	2.63 b[Z]	2.75	12.00 b	89.79	VS[X]	I[Y]	16.18	14.79	11.52
500	2.94 b	2.76	18.25 a	88.94	S	MT	16.97	15.29	12.04
1,000	3.62 a	3.08	17.00 a	91.93	M	MT	17.01	15.41	10.89
1,500	3.43 ab	2.81	18.25 a	89.24	M	MT	17.32	15.60	9.65
2,000	4.04 a	2.96	15.75 a	89.71	M	MT	16.98	15.86	12.37
Average	3.33	2.87	16.25	89.92	–	–	16.89	15.39	11.29
C.V.,%	12.72	13.04	14.63	2.09	–	–	5.89	7.18	17.69
		NS		NS			NS	NS	NS

[Z] Means within columns followed by the same letter do not differ significantly at the 5% level as measured by Duncan's New Multiple Range Test.

[X] VS = Very small, S = Small, M = Medium

[Y] I = Immature, MT = Mostly mature

length, hence were considered very small in size. Those from the 500 ppm and 1,500 ppm were greater than 3 cm but less than 4 cm in length, hence were considered small in size. Medium size fruits which were greater than 4 cm but less than 6 cm in length were harvested from 1,000 and 2,000 ppm Ca levels. Leonard (43) found that fruit size and shape are positively correlated in several instances with seed number and distribution. Immature fruits were harvested from the control treatments whereas other Ca levels had mostly mature fruits. Most of the mature fruits were red ripe at harvest. It may be suggested that the occasional high temperatures encountered during the test period could have hastened fruit ripening.

The effects of Ca levels on the mineral content of the stems are presented in table 45. The treatments had no significant effect on P, K, Mg and Fe. Percent Ca, Mn and Zn were significantly affected by Ca treatments. The P, K, Ca and Mg showed a general increase in the stem with increase in Ca level up to 1,500 ppm. Above this level, a slight drop in their content was observed. On the other hand, Mn, Zn and Fe generally increased with decrease in Ca level and pH. The pH ranges observed were 5.5 to 5.7, 6.2 to 6.5, 7.5 to 7.7, 7.9 to 8.0, and 8.2 to 8.5 for 0, 500, 1,000, 1,500 and 2,000 ppm Ca levels respectively. The micronutrients, Mn, Zn and Fe become less available as the pH increases.

Percent mineral content of the leaf was not significant

Table 45.

Effects of levels of calcium on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

$CaCO_3$ treatment (ppm)	Tissue concentration (%) stem						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.65	0.64	0.24 c[z]	0.28	0.100 a	0.0062 a	0.0094
500	1.21	0.79	0.43 ab	0.29	0.044 b	0.0022 b	0.0063
1,000	1.06	0.84	0.52 ab	0.32	0.036 b	0.0018 b	0.0034
1,500	1.17	0.83	0.53 a	0.31	0.036 b	0.0017 b	0.0058
2,000	0.82	0.80	0.51 ab	0.30	0.032 b	0.0018 b	0.0044
Average	0.98	0.78	0.45	0.30	0.050	0.0034	0.0059
	NS	NS		NS			NS

[z] Means within columns followed by the same letter do not differ significantly at the 5% level as measured by Duncan's New Multiple Range Test.

for K and Fe (Table 46). The P, Ca, Mg, Mn and Zn were significantly affected by Ca levels. A general increase in macronutrients with increase in Ca treatments was observed. Micronutrients showed a general increase as the Ca level decreased.

The effects of Ca levels on mineral content of bell pepper fruits are presented in table 47. The P, K, Ca, Mg, Zn and Fe contents were not significantly affected by Ca treatments. Percent Mn content of the fruits was significantly affected by Ca treatments. Although the amount of nutrients taken by the pepper plants may depend up the soil pH, other factors such as the cation exchange capacity of the soil, type of soil colloid and nature of complementary ions adsorbed on the exchange complex may account for the variations in the nutrient distribution in the plant tissues. Also involved are the environmental conditions and selective absorption of ions. Parker and Truog (65), observed that Ca is essential for the mobilization of P from the growth medium to the plant. Hamson (34) noted that Ca content of tomato fruits was positively correlated with the firmness in fresh tomato.

The coefficients of simple correlation among yield, yield components and some other characters studied are presented in table 48. Each correlation described the relative variation of a component in response to variations in another. Yield generally was positively correlated to the yield components

Table 46.

Effects of levels of calcium on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

$CaCO_3$ treatment (ppm)	Tissue concentration (%) leaf						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.66 ab[z]	1.17	0.26 c	0.13 c	0.150 a	0.015 a	0.039
500	0.77 a	1.24	0.75 b	0.21 ab	0.117 ab	0.120 a	0.026
1,000	0.77 a	1.45	0.95 ab	0.19 b	0.096 b	0.012 a	0.023
1,500	0.65 ab	1.26	0.89 ab	0.20 ab	0.094 b	0.010 a	0.022
2,000	0.63 b	1.19	1.04 a	0.24 a	0.084 c	0.009 b	0.021
Average	0.70	1.26	0.78	0.19	0.108	0.011	0.026
		NS					NS

[z] Means within columns followed by the same letter do not differ significantly at the 5% level as measured by Duncan's New Multiple Range Test.

Table 47.

Effects of levels of calcium on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Summer, 1982).

$CaCO_3$ treatment (ppm)	Tissue concentration (%) fruit						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.44	0.57	0.10	0.17	0.032 a[z]	0.0024	0.0052
500	0.43	0.62	0.12	0.17	0.014 b	0.0023	0.0060
1,000	0.47	0.73	0.11	0.18	0.009 c	0.0017	0.0061
1,500	0.43	0.64	0.13	0.19	0.009 c	0.0021	0.0062
2,000	0.39	0.61	0.09	0.15	0.007 c	0.0020	0.0061
Average	0.43	0.63	0.11	0.17	0.014	0.0021	0.0059
	NS	NS	NS	NS		NS	NS

[z] Means within columns followed by the same letter do not differ significantly at the 5% level as measured by Duncan's New Multiple Test.

Table 48.

Coefficients of simple correlation among yield, yield components and some other characters studied (Summer, 1982).

	Plant height	Plant width	# of branches	Leaf area	Leaf abscission	# of flower	Yield	Fruit length	Fruit diameter	# of lobes	Fruit abscission
Plant height	–	0.71**	0.10	-0.01	0.72**	0.60*	0.34	0.18	0.14	0.19	0.45
Plant width		–	0.26	0.50*	0.85**	0.47	0.69**	0.65**	0.64**	0.47	0.17
# of branches			–	0.07	-0.84**	0.02	0.01	0.11	0.47	0.61**	-0.12
Leaf area				–	0.27	0.39	0.72**	0.80**	0.77**	0.34	-0.14
Leaf abscission					–	0.30	-0.05	0.04	0.14	0.44	0.59*
# of flowers						–	0.78**	0.50*	0.52*	0.06	0.57*
Yield							–	0.79**	0.78**	0.18	-0.10
Fruit length								–	0.88**	0.38	-0.04
Fruit diameter									–	0.55*	-0.16
# of lobes										–	-0.31
Fruit abscission											–

* Significant at the 0.05 level of probability.

** Significant at the 0.01 level of probability.

and other characters except leaf and fruit abscissions. It could be noted that characters positively correlated with yield are more important for pepper production than those that had negative correlations. Kirby (41) reported that the relative importance of a particular yield component will depend on the cultivar.

Greenhouse Rate Experiment (Fall, 1982)

This experiment was also conducted to determine the effects of $CaCO_3$ and soil pH on plant height, yield and other yield components of bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant #4 grown in the greenhouse in the fall of 1982. The effects of levels of Ca on plant height, number of branches and number of flowers were not significant (Table 49). Plant width, leaf area, leaf abscission, yield and fruit length were significantly affected by Ca treatments. The application of 1,500 ppm $CaCO_3$ resulted in the greatest plant width value of 31.95 cm. The smallest plant width was 26.23 cm observed in the controls. This value was significantly lower than other values recorded except for 29.79 cm observed in the 1,000 ppm Ca treatments. The higher plant with values in contrast to their corresponding plant heights may suggest that stunted plant growth may result in bushy canopy for some pepper cultivars. Leaf area was greatest in the 1,500 ppm Ca treatments which had a pH range of 7.2 to 7.4. Other pH values recorded were 5.4 to 5.6, 6.0 to 6.3, 7.1 to 7.2, and 7.5 to 7.7 for 0, 500, 1,000 and 2,000 ppm $CaCO_3$ treat-

Table 49.

Effects of levels of calcium on plant height, plant width, number of branches, average leaf area, leaf abscission, number of flowers, yield and fruit length of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

$CaCO_3$ treatment (ppm)	Plant height (cm)	Plant width (cm)	Number of branches/plant	Av. leaf area (sq cm)	Leaf abscission per plant	Number of flowers/plant	Yield per plant (gm)	Fruit length (cm)
0	25.18	26.23 b[z]	5.00	55.24 c	7.88 a	8.75	20.04 b	5.14 b
500	25.25	30.31 a	5.50	87.56 b	6.63 a	9.50	55.61 a	6.35 a
1,000	29.49	29.79 ab	5.50	84.45 b	4.63 b	10.93	60.01 a	6.14 a
1,500	27.64	31.95 a	5.25	96.84 a	4.13 b	10.13	65.27 a	6.64 a
2,000	27.19	31.35 a	6.00	89.34 b	4.25 b	9.88	62.41 a	6.61 a
Average	26.97	29.93	5.45	82.69	5.50	9.84	52.67	6.18
C.V.,%	10.23	8.00	11.68	4.71	20.40	11.63	13.57	7.51
	NS	NS				NS		

[z] Means within columns followed by the same letter do not differ significantly at the 5% level as measured by Duncan's New Multiple Range Test.

ments, respectively. The smallest leaf area recorded was 55.24 sq cm in the control treatments. This value was significantly lower than other values observed. The greatest leaf abscission recorded was 7.88 which was noted in the control. The lowest value observed was 4.13 which was significantly lower than most of the other values recorded. Leaf abscission generally decreased with increase in Ca and pH levels. The greatest number of flowers was 10.93 observed in the 1,000 ppm $CaCO_3$ treatments with a pH range of 7.1 to 7.2. The smallest value was 8.75 in the control treatments. Flower opening was earlier under high Ca level as compared to low Ca treatments. The greatest yield of 65.27 g per plant was recorded from the 1,500 ppm Ca treatments. The smallest yield was 20.04 g per plant in the control treatments. Yield generally increased with increase in Ca treatments up to 1,500 ppm Ca level. Ozaki and Hortenstine (60) stated that application of lime increased yield of 'Florida Giant' peppers only if the acid-soluble Ca level was below 300 lbs per acre. On such soils application of 2,000 lb agricultural limestone per acre resulted in the highest yield of marketable peppers. The greatest fruit length was 6.64 cm which was observed at the 1,500 ppm Ca level. The smallest fruit length was 5.14 cm in the control treatments.

The effects of levels of Ca on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, maturity and percent dry matter are presented in table 50. Calcium

Table 50.

Effects of levels of calcium on fruit diameter, number of lobes, bud drop, fruit abscission, fruit size, fruit maturity and percent dry matter of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

$CaCO_3$ treatment (ppm)	Fruit diameter (cm)	Number of lobes	Bud drop per plant	Percent fruit abscission/plant	Fruit size	Fruit maturity	% D.M. stem	% D.M. leaf	% D.M. fruit
0	3.24 b[Z]	3.25	7.13 a	83.01	M[X]	I[Y]	14.38 b	9.77 c	6.25
500	4.89 a	3.13	5.63 ab	85.25	L	MT	16.08 a	11.07 b	6.30
1,000	4.91 a	3.63	3.75 b	80.56	L	MT	17.13 a	12.21 a	6.27
1,500	4.91 a	3.25	3.50 b	81.04	L	MT	17.22 a	12.79 a	6.54
2,000	5.32 a	3.50	4.50 ab	82.18	L	MT	16.30 a	12.58 a	6.55
Average	4.65	3.35	4.90	82.41	-	-	16.22	11.68	6.40
C.V.,%	5.98	11.87	17.73	7.96	-	-	11.78	5.22	4.08
		NS		NS					NS

[Z] Means within columns followed by the same letter do not differ significantly at the 5% level as measured by Duncan's New Multiple Range Test

[X] M = medium, L = Large

[Y] I = Immature, MT = Mostly mature

treatment had no significant effects on number of lobes, fruit abscission and fruit percent dry matter. Fruit diameter, bud drop, stem and leaf percent dry matter. The greatest fruit diameter recorded was 5.32 cm which was observed in the 2,000 ppm Ca treatments. The smallest value was 3.24 in the control treatments. This value was significantly lower than the other values recorded. The greatest bud drop was 7.13 which was observed in the control treatment. The lowest bud drop was 3.50 in the 1,500 ppm Ca level. This was significantly lower than the 7.13 recorded for the controls. The high bud drop noted for the control may suggest that insufficient Ca may lead to embryo abortion by reducing auxin supply from the abscission zone. Adverse weather condition at the time of bloom may interfere with pollination, resulting in bud drop. Calcium treatments resulted in medium size fruits for the control. Such fruits were greater than 4 but less than 6 cm in length. The large size fruits harvested from other treatments were greater than 6 cm in length. Immature fruits were harvested from the control whereas other Ca treatments had mostly mature fruits. The greatest percent dry matter in the stems was 17.22 in the 1,500 ppm Ca treated plants. The smallest dry matter percent was 14.38 in the control plants. The greatest percent dry matter in the leaves was 12.79 in the 1,500 ppm Ca treated plants. The smallest value of 4.77 was recorded at the control levels. Percent dry matter generally increased with increase in Ca levels and soil pH.

The effects of levels of Ca on the mineral content of the stems are presented in table51. The treatments had no significant effect on P, K and Fe. The Ca, Mg, Mn and Zn contents were significantly affected by Ca treatments. The P, Ca and Mg generally increased in the stems with increase in Ca level and soil pH. With the exception of 4.85 observed at the control for K content, other values also increased in a similar manner as the other macronutrients. The micronutrients contents declined at high Ca levels.

Percent mineral content of the leaves was significantly affected by Ca treatments except for P and Fe (Table 52). While the macronutrients, P and Ca showed a general increase with increase in Ca treatments, K and Mg showed a general decrease. The micronutrients, Mn, Zn and Fe were higher at low pH and Ca levels.

Percent mineral content of the fruits was significantly affected by Ca treatments except for P(Table 53). The Ca content increased with the increase in Ca level up to 1,500 ppm, whereas Mg and K had a general decrease with increased Ca treatments. Micronutrients were higher at low soil pH and low Ca levels. It may be stated that the overall mineral content of the bell pepper plants were greatest for the leaves, followed by the stems and finally by the fruits. The inconsistency noted in the fruits' mineral content could be due to the variations in maturity stages at harvest.

Table 51.

Effects of levels of calcium on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

$CaCO_3$ treatment (ppm)	Tissue concentration (%) stem						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.07	4.85	0.63 b[z]	0.40 b	0.034 a	0.0041 a	0.0120
500	0.06	3.94	1.18 a	0.40 b	0.012 b	0.0016 c	0.0110
1,000	0.09	4.18	1.23 a	0.50 a	0.007 b	0.0018 bc	0.0070
1,500	0.08	4.27	1.49 a	0.53 a	0.007 b	0.0024 b	0.0100
2,000	0.10	4.49	1.40 a	0.47 ab	0.009 b	0.0018 bc	0.0090
Average	0.08	4.35	1.19	0.46	0.014	0.0023	0.0098
	NS	NS					NS

[z] Means within colums followed by the same letter do not differ significantly at the 5% level as measured by Duncan's New Multiple Range Test.

Table 52.

Effects of levels of calcium on mineral content of greenhouse grown bell pepper (Capsicum annuum L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

$CaCO_3$ treatment (ppm)	Tissue concentration (%) leaf						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.29	8.18 a[Z]	1.50 c	0.81 a	0.160 a	0.018 a	0.026
500	0.32	6.63 b	2.87 b	0.75 ab	0.048 b	0.009 b	0.025
1,000	0.34	6.29 b	2.94 b	0.67 bc	0.031 c	0.004 c	0.019
1,500	0.33	6.24 b	3.11 ab	0.68 b	0.031 c	0.003 c	0.020
2,000	0.38	6.29 b	3.36 a	0.61 c	0.04 bc	0.004 c	0.021
Average	0.33	6.72	2.76	0.70	0.062	0.008	0.023
	NS						NS

[Z] Means within columns followed by the same letter do not differ significantly at the 5% level as measured by Duncan's New Multiple Range Test.

Table 53.

Effects of levels of calcium on mineral content of greenhouse grown bell pepper (*Capsicum annuum* L.) cv. Keystone Resistant Giant #4 (Fall, 1982).

$CaCO_3$ treatment (ppm)	Tissue concentration (%) fruit						
	P	K	Ca	Mg	Mn	Zn	Fe
0	0.36	3.06 a[z]	0.12 b	0.21 a	0.0110 a	0.0050 a	0.0080 a
500	0.37	2.85 ab	0.17 a	0.18 b	0.0042 b	0.0042 a	0.0078 a
1,000	0.32	2.71 b	0.17 a	0.16 c	0.0032 b	0.0027 b	0.0060 b
1,500	0.33	2.65 b	0.19 a	0.17 c	0.0032 b	0.0021 b	0.0061 b
2,000	0.38	2.79 b	0.17 a	0.17 c	0.0034 b	0.0020 b	0.0057 b
Average	0.35	2.81	0.16	0.19	0.0051	0.0032	0.0067
	NS						

[z] Means within columns followed by the same letter do not differ significantly at the 5% level as measured by Duncan's New Multiple Range Test.

The coefficients of simple correlation among yield, yield components and other characters studied are presented in table 54. Each correlation described the relative variation of a component in response to variations in another. Yield generally was positively correlated to the other yield components except number of branches and leaf abscission. These data suggest that characters which were positively correlated with yield are more important than negatively correlated characters for pepper fruit production. Kirby (41) reported that the relative importance of a particular yield component will depend on the cultivar, in contrast to the findings of Laude (42), who noted that season rather than cultivar determined the relative importance of a particular yield component.

Table 54.

Coefficients of simple correlation among yield, yield components and some other characters studied (Fall, 1982).

	Plant height	Plant width	# of branches	Leaf area	Leaf abscission	# of flowers	Yield	Fruit length	Fruit diameter	# of lobes	Fruit abscission
Plant height	–	0.32	0.10	0.37	–0.25	0.62**	0.37	0.28	0.17	–0.0021	–0.260
Plant width		–	–0.05	0.72**	–0.37	0.50*	0.77**	0.64**	0.65**	0.2400	0.130
# of branches			–	–0.29	0.34	–0.07	–0.02	–0.22	–0.27	0.3100	0.020
Leaf area				–	–0.62**	0.63**	0.91**	0.80**	0.86**	0.0500	0.150
Leaf abscission					–	–0.19	–0.66**	–0.54*	–0.69**	–0.1400	0.120
# of flowers						–	0.73**	0.45	0.54*	–0.1300	0.047
Yield							–	0.75**	0.90**	0.3000	0.130
Fruit length								–	0.74**	0.0100	0.100
# of lobes									–	0.2700	0.250
Fruit abscission										–	0.130
											–

* Significant at the 0.05 level of probability.

** Significant at the 0.01 level of probability.

SUMMARY

In the spring, summer and fall of 1982, bell pepper (*Capsicum annuum* L.) cv. 'Keystone Resistant Giant #4' was subjected to either sources or levels of Ca in the greenhouse. The $CaCO_3$ treated plants had significantly better growth, greater yield and more nutrient uptake than the control plants during the three seasons of plantings. Quality of growth, earliness of flowering and fruit development were better during the fall plantings for all treatments. The $Ca(NO_3)_2$ treatments favored more vegetative growth on short internodes during the summer plantings. Although a general yield depression was observed, spring plantings had greatest total fruit production. Depression of soil pH with $CaSO_4$ applications was greatest in fall treatments. This resulted in decreased macronutrient availability and increased Mn concentrations in the soil solution and uptake, to induce interveinal chlorosis on upper leaves of pepper plants. The excessive heat of summer caused poor fruit-setting, limited pollination, nutrient uptake, more blossom drop and production of smaller fruits, resulting in an overall lower yield than either fall or spring plantings. Total mineral content was greatest in the leaves, then stems and finally fruits. Leaf tissue analysis was therefore essential for estimating the Ca uptake by pepper plants. Uptake was greatest in fall, then spring and lastly summer.

Dry matter percentages were generally greater in the stems, then leaves and lastly fruits in all seasons. Summer plants had greatest overall dry matter percentages due to decreased water content from greater transpiration. Bell pepper growth, yield and macronutrient uptakes generally increased significantly with increased levels of Ca up to 1,5000 ppm of Ca applied as $CaCO_3$. Micronutrients generally decreased with increase in Ca level and soil pH. A pH range of 7.2 to 7.4 obtained by applying 1,500 ppm $CaCO_3$ during the fall plantings was considered optimum for pepper growth and yield in Cahaba Silt Loam soil under the greenhouse condition. Above this, bell pepper growth and development declined and yield decreased. Percent dry matter generally increased significantly with increased level of Ca in the stems, leaves and fruits. Fruit yield was positively correlated with plant height, number of branches, leaf area, number of flowers, length of fruit, diameter of fruit and number of lobes. Leaf area was more important for pepper fruit yield than any other character studied. Fruit size and degree of maturity increased with increased level of Ca. Summer fruits matured earlier and were mostly red ripe at harvest. In conclusion, it may be stated that incorporation of 1,500 ppm of Ca as $CaCO_3$ ina 14 Kg plastic pot is optimum for desirable condition for bell pepper production on Cahaba Silty Loam soil if the soil pH is between 4.9 and 5.0 under greenhouse conditions. Since Ca content in the tissues generally increased with increase in $CaCO_3$ level, it may suggest that $CaCO_3$ is a satisfactory means of supplying Ca to plants.

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EXAMINATION AND THESIS REPORT

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Major Field: Horticulture

Title of Thesis: Some Effects of Calcium on Growth, Yield and Mineral Content of Pepper (Capsicum annuum L.).

Approved:

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